Planes, Trains, and Automobiles: Savings Potential of Utilizing Multi-Modal Transport for Depositioning Cargo in the CONUS

GRADUATE RESEARCH PAPER

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Abstract

This paper analyzes the benefits of utilizing a multi-modal approach (utilizing trucks and/or rail) for cargo transport from West/East Coast bases to inland CONUS cargo destinations rather than flying cargo to its final destinations. The author proposes that adjusting current operations to a more multi-modal model will provide significant savings in operational, variable, fuel costs, flying hours, and mission hours.

The author performed a case study approach focusing on C-17 and C-5 missions that operated from 1 Jul 2011 – 30 Sep 2011 in determining the cost-savings opportunities utilizing a multi-modal approach. Using these missions, the author identified “opportunities” for savings and calculated the operational, variable, and fuel costs of operating these missions. The author then calculated the cost of utilizing a multi-modal approach to move the cargo from a West/East Coast base vice flying it in aircraft to determine the overall savings.

Based on the paper’s findings, significant cost and operational savings for the US military can be realized by adjusting Air Mobility Command missions to allow for cargo to be disembarked at West/East Coast bases for ground transport via truck and/or rail to the cargo’s ultimate destinations.

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Tim Gonyea

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Planes, Trains, and Automobiles: Savings Potential of Utilizing Multi-Modal Transport for Depositioning Cargo in the CONUS

I. Introduction

> "Amateurs worry about strategy. Dilettantes worry about tactics. Professionals worry about logistics."
>
> -- Unknown

General Issue

Determining the most effective and least costly way of transporting equipment back from the United States' forward operating bases is an issue that currently affects today's military planners and is one of growing importance as the conflict in Afghanistan transitions towards completion. Based on Afghanistan's land-locked location and questionable access to its nearest sea port (Karachi, Pakistan) due to political sensitivities, a good majority of military equipment in Afghanistan will have to return to the United States via military aircraft. According to the current construct, most military aircraft will carry equipment directly from Afghanistan with a final destination of the equipment's CONUS home station, stopping for fuel at various locations along the way. However, this current way of "doing business" may not be the most cost-effective considering air transport is the most expensive of all methods of travel albeit the most expeditious way of transporting items. While it is certainly possible to transport equipment to the destination bases' nearest airfield utilizing all types of military transporters (C-5, C-17, C-130), there could also be another potential and less costly solution in transporting the equipment

from East/West Coast bases using alternate means of transportation (trains, trucks, etc.). Utilizing such a concept could potentially save millions of dollars in costs while allowing the aircraft to fly on other missions and increase the effectiveness and efficiency of Air Mobility Command and USTRANSCOM missions.

Background

On October 4, 2001, US forces attacked Afghanistan beginning their air campaign in an attempt to defeat the Taliban government and to root out the terrorists who attacked our country only a month earlier. Those initial attacks were the beginning in what has come to be America's longest running war, currently at 151 months of fighting with an expected drawdown of America's troops from Afghanistan beginning in 2012 and ending in 2014 with a transition of responsibilities to the Afghan National Army.

The country of Afghanistan is located in Southwest Asia and is landlocked by other Southwest Asian countries (see Figure 1 below). As a result, most of the supplies in the country of Afghanistan will have to withdrawn by one of three ways: 1) By way of the Northern Distribution Network (a multi-modal network through many of the former Soviet republics) terminating at the naval ports of Riga, Latvia or Ponti, Georgia, 2) By traveling south through Pakistan to the naval port at Karachi, and 3) By aircraft departing direct from Afghani airfields. Due to the sheer complexity of the withdrawal from a landlocked nation and the vast amount of equipment to be transported from Afghanistan, aircraft will need to play a significant role in the depositioning of supplies from Afghanistan back to CONUS.

Figure 1: Southwest Asia Map and Location of Afghanistan

According to the current construct, these aircraft will pick up a unit's equipment at an air base in Afghanistan and transport that equipment back to the unit's stateside location. The vast majority of these aircraft will return westbound by way of Germany and other intermediary stops for fuel and crew changes prior to their arrival at the equipment's home station. At this point, the aircraft will continue their mission by returning to their home base and resetting for their next mission.

While this airlift of equipment is altogether necessary to complete the redeployment of combat units back to CONUS, it is also a very expensive proposition. According to the AF Energy Plan, the Air Force accounts for 64% of the fuel consumed by the Armed Services, and of this 64%, 84% goes to aviation operations. Air mobility aircraft account for 52% of the aviation operations expenditures according to mission type (AF Energy Plan, 2010:3-4). In fact, in 2008 alone, the USAF consumed approximately 2.5 billion gallons of aviation fuel at a cost of $7.56 billion (AF Energy Plan, 2010:3-4). Thus, airlift, while a necessary component to the successful redeployment of those forces still currently in Afghanistan, remains a very high cost endeavor and a huge component of our military's budget. As a result, the Air Force and the US government in general are looking for ways to conserve fuel whenever and wherever possible. According to the AF Energy Plan:

> "Due to the magnitude of energy consumed by the Air Force, any actions taken to reduce energy consumption and procure alternative/renewable energy sources are significant in their potential impact for enhancing energy and national security" (AF Energy Plan, 2010:3-4).

Due to this increased focus on saving money and on reducing energy consumption by the US Air Force, the current construct of using military airlift to transport equipment from Afghanistan to inland CONUS bases must be examined to determine if any potential savings can be generated by adjusting this paradigm.

Problem Statement

This purpose of this research is to show some of the economic and military benefits of utilizing East and West Coast cargo offload points (APODs) for military aircraft transporting equipment back from Afghanistan to select CONUS locations vice

flying the equipment to its final inland destination and returning the aircraft to the coast for follow on mission(s). The disembarked equipment would reach its final destination via rail and/or truck, providing significant savings to Air Mobility Command and USTRANSCOM in the way of fuel savings and reduced costs.

Research Objectives/Questions/Hypotheses

Air Mobility Command is USTRANSCOM's air component in supporting theater COCOM requirements. As such, Air Mobility Command aircraft are called upon by all COCOMs to support their varying needs for transport of personnel and supplies. This mission requires AMC aircraft to conduct operations around the world on a daily basis supporting all branches of Services and other government entities.

As AMC flies a multitude of missions, looking at all of these missions is not practical. Therefore, the author limited the scope of this study to looking at AMC missions that transported cargo from Germany (Ramstein Air Base or Spangdahlem Air Base) to CONUS to the cargo's inland destinations. Most, if not all, of this cargo was returning from Afghanistan to its owning unit for refurbishment and reset.

The overall objective of this paper is to ascertain the cost differences and potential savings of offloading this CONUS-bound cargo at East/West Coast bases and have the equipment shipped to its final destinations via truck and/or rail. An additional benefit to having Air Mobility Aircraft drop off cargo at East/West Coast bases is that most AMC aircraft are based in these locations. Subsequently, if the missions can be scheduled to drop off cargo at the aircraft's home station, then that particular aircraft is freed up to fly

other AMC missions rather than waiting for the aircraft to fly to an inland CONUS location, offload cargo, and then return home.

The research questions addressed in this paper are:

1) What are the characteristics of air, rail, and truck freight transportation?

2) What are the basics of a redeployment or reset of Army equipment?

3) What are the fuel, variable, and operational costs of operating C-17 and C-5 aircraft between the West/East Coast bases and inland CONUS destinations?

4) What is the cost of transporting equipment via truck and/or rail from select West/East Coast bases to inland CONUS destinations?

5) What are the cost savings between transporting cargo from select West/East Coast bases by rail/truck versus air?

6) What are the other benefits from utilizing multi-modal transport from West/East Coast bases (flight hours savings, mission hours, etc)?

7) What is the additional workload for Aerial Ports at these selected West/East Coast bases and can they absorb the additional capacity in this proposal?

8) Are rail options feasible at the selected cargo debarkation locations?

The researcher hypothesizes that there is a great savings potential in transporting equipment from East/West Coast bases to inland CONUS destinations using a multi-modal transport framework as opposed to utilizing air transport (AMC aircraft) to fly to the cargo's final destinations based on the savings in fuel and aircraft variable and operational hours. Also, such an initiative would free up AMC aircraft to return to home-station earlier, saving flight and mission hours, and allow the aircraft to be utilized on

future missions, providing greater aircraft and crew capacity to Air Mobility Command and USTRANSCOM.

Research Focus

AMC/A9 gathered data from 618 Air and Space Operations Center (TACC) on C-5 and C-17 Channel, SAAM, and Contingency missions flown from 17 May 2011 – 28 Oct 2011. The researcher refined this data and only analyzed that information from the 3rd quarter, 2011 (1 Jul – 30 Sep). The author further narrowed the scope to only those missions transporting cargo from Europe to the United States, including those missions that had a required fuel stop en route in Gander, Canada or Bangor, ME. Based on this sampling of data, the researcher examined several cargo destinations and aircraft home stations to determine the missions that could provide possible savings opportunities if they were adjusted to meet the hypothesis. Once these missions were identified, the author used this sample size (n = 1439) to analyze and generate any final findings/recommendations.

Chapter II presents a Literature Review of applicable information that relates to this research proposal to include the nature of equipment redeployment, what types of missions AMC operates, what the cost is of flying AMC aircraft (fuel, variable, and operational costs), and what the benefits/drawbacks are of utilizing various modes of transport. Chapter III will go into detail on the Methodology utilized in the author's analysis and go into detail into the missions identified as potential savings opportunities. Chapter IV will present the results and analysis of the findings, followed by the

Conclusion, any subsequent recommendations, and possible areas for future study in Chapter V.

II. Literature Review

Chapter Overview

This literature review examines several sources to expand and build upon the proposal discussed in the previous chapter. The beginning portion deals with current US troop levels in Afghanistan, the possible troop withdrawal timeline, and what timeline must be met when redeploying troops and equipment back to the United States. This portion of the literature review seeks to frame the future requirements of Air Mobility Command in supporting such an operation. The review continues with discussing aircraft (C-17 and C-5) operating characteristics in order to properly analyze operating and fuel costs. Lastly, the review will touch upon the characteristics between air, rail, and truck transport.

Total Number of US Soldiers in Afghanistan and Redeployment Information

In a June 2011 address, President Obama laid out his plan to cut US troop strength a grand total of 30,000 troops by September 2012. This effort began immediately with a removal of 10,000 troops prior to the end of 2011 (Dorning, 2011). Following the drawdown of 30,000 US troops, the troop levels left serving in Afghanistan as of October 2012 will stand at around 68,000 troops (Bennett, 2012).

According to <u>Afghanistan Index: February 29, 2012</u> authors Ian S. Livingston and Michael O'Hanlon of the Brookings Institution, US Soldiers currently deployed to Afghanistan in support of Operation Enduring Freedom number 89,000 as of February 29, 2012 (Livingston, 2012:4). An additional 23,000 US troops and equipment are

planned to be deployed back stateside by September 2012, meeting the President's mandate of removing 30,000 troops from Afghanistan by September 2012.

The vast majority of these troops returning are US Army Soldiers who have been deployed in periodic rotations in support of ISAF and Operation Enduring Freedom missions. Along with these Soldiers comes a vast array of unit equipment that will need to subsequently redeploy back to CONUS with their personnel for refurbishment and reset. Some equipment will travel to various naval seaports along the Northern Distribution Network or south to Karachi, Pakistan for travel home on US Navy ships. Other equipment, however, will be transported by military aircraft from Afghanistan to the CONUS.

There are several advantages to utilizing military aircraft to transport a unit's equipment home. The first is that the unit can retain good accountability of its equipment by traveling along with it rather than traveling separate from its equipment (i.e. Soldiers traveling home on US commercial rotators and equipment on US Navy ships). The second advantage is of the speed in which the unit's equipment can be transported back to the unit for refurbishment and reset. Upon departing Afghanistan onboard a military aircraft, a unit's personnel and equipment can easily make it back to its stateside home base within 24-48 hours in most cases. However, these advantages come with a price since utilizing air transport is extremely expensive based on operating costs of aircraft and fuel. Based on this, the question becomes: what is the US Army requirement for when it needs to receive its equipment at its home station and does it necessarily have to travel via air (the most expensive method)?

According to *Joint Publication 3-35 Deployment and Redeployment Operations*, redeployment is defined as: “the transfer of forces and materiel to support another joint force commander’s operational requirements, or to return personnel, equipment, and materiel to home/demobilization stations for reintegration/out-processing” (JP 3-35, 2007:VI-1). The regulation goes on further to discuss the movement of the unit following the arrival at the Port of Debarkation (POD):

> “Onward movement by common-user or commercial lift from a common-user surface POD to the home and/or demobilization station or point of origin is arranged by SDDC in conjunction with Service and/or the force-designated movement control center (MCC) or element. Onward movement from AMC APODs is the responsibility of AMC, and from commercial and/or non-AMC military APODs onward movement is the responsibility of the personnel assistance points or ITO and/or traffic management office responsible for the geographic area of those ports” (JP 3-35, 2007:VII-9).

Thus far, there has not been a directed mode of transportation or a timeframe specified for when unit equipment must reach its final destination.

FMI 3-35 Army Deployment and Redeployment delves a bit further into the specifics of the redeployment process stating:

> “Redeployment involves the return of personnel, equipment, and materiel to home and/or demobilization stations and is considered as an operational movement critical in reestablishing force readiness. The CCDR defines the conditions for redeployment. The same elements that operate and manage the theater distribution system during deployment and sustainment will usually perform support roles during redeployment. Redeployment planning is an integral part of employment planning and should be coordinated with mission termination or transition plans.” (FMI 3-35, 2011: 5-1).

This expanded definition is important since it conclusively states that redeployment is “considered as an operational movement critical in reestablishing force readiness” (FMI 3-35, 2011: 5-1). Thus, it is important for equipment to make a timely return to its home station so that this process can begin. FMI 3-35 goes on to state that:

> "5-17. The combination of strategic airlift and sealift provides the capability to redeploy forces, albeit in different timeframes and along separate routes. Personnel are transported by strategic airlift to the destination APOD and then moved by bus to the destination installation. Vehicles, unit equipment, and containers are moved by strategic sealift to the designated SPOD, unloaded, and transported by convoy, commercial truck, or rail to the destination installation.
>
> 5-18. It is extremely important for the redeploying unit, assisted by their home station ITO, to maintain visibility of their vehicles and unit equipment. A small investment in maintaining visibility throughout the redeployment pipeline can be rewarded by having your vehicles equipment delivered to the right place at the right time. Otherwise there may be a delay in beginning the reset phase of ARFORGEN.
>
> MOVEMENT TO HOME OR DEMOBILIZATION STATION
>
> 5-19. The destination for active component units is normally their home station whereas reserve component units return through a demobilization station. Typically the demobilization station is the same installation that served as the unit's mobilization station.
>
> 5-20. The supporting installation is responsible to assist returning forces until they reach their destination. The installation coordinates the support for the arrival ports and airfields and establishes en route sites as required by the redeployment plan. Once the unit vehicles and equipment arrive at the SPOD, the destination installation has the primary role of coordinating with SDDC for onward movement. The unit is responsible to provide load/unload teams and drivers at the POD and railhead. The supporting installation has the following responsibilities at the POD—
>
> - Stage equipment for movement to the final destination.
> - Coordinate for customs clearance inspections.
> - Complete equipment inspections and process movement documentation" (FMI 3-35, 2007: 5-4).

According to the above, there would have to be slight changes to verbiage in FM 3-35 to specify procedures for this paper's proposal. Currently, most Army equipment does in fact travel via sealift to SOE to the conflict and on sealift to SPOD from the conflict. However, there is also equipment that travels on mobility aircraft that, up until this point, when returning home would travel to the closest APOD to the unit and then travel via

truck, rail, or convoy to its final destination. This researcher proposes that verbiage should be added to this regulation to allow for mobility aircraft to disembark cargo at their "home station or other capable" APOD and follow that up with similar words as to the third sentence in FM 3-35 paragraph 5-20.

Due to the fact that the US Army typically plans on equipment traveling via sealift from overseas to a CONUS seaport and then further travel via rail/truck/convoy (based on the references in FM 3-35), this author would see no significant issues or delays in the Army's receipt of their equipment if actions are taken to allow mobility aircraft the ability to disembark cargo at their home station or other APODs for subsequent travel on rail/truck/convoy. According to the SMS TRANSCOM "Transportation Wizard" application, the amount of time that USTRANSCOM advertises for one pallet to travel from Karachi, Pakistan to Gray Army Airfield, WA is 45 days (sms.transcom.mil, 2012). Therefore, military aircraft transporting a similar pallet would conceivably arrive to a CONUS location well in advance of sealift arriving to a port, putting the ultimate arrival of the cargo to its final destination well ahead of that of any sealift options that are currently utilized today.

Based on reviewing Joint and Army regulations, this author was unable to locate a firm required delivery date for unit equipment returning to its home base. However, based on the above information and discussions with a senior leader at 1st Theater Sustainment Command, the target date for equipment to be "married up" to its personnel back at home station is within ninety days. Clearly, this target date is well within the timeframe needed in support of this paper's proposal.

Airlift and Its Various Mission Types

The Department of Defense and the United States Armed Services utilize air mobility in order to support operations around the globe. JP 3-17 defines and discusses airlift as:

> "Airlift operations transport and deliver forces and materiel through the air in support of strategic, operational, and/or tactical objectives. Airlift offers its customers a high degree of speed, range, and flexibility. Airlift enables commanders to respond and operate in a wide variety of circumstances and time frames that would be impractical through other modes of transportation.
>
> Airlift supports the US National Military Strategy by rapidly transporting personnel and materiel to and from or within a theater. Airlift is a cornerstone of global force projection. It provides the means to rapidly deploy and redeploy forces, on short notice, to any location worldwide. Within a theater, airlift employment missions can be used to transport forces directly into combat. To maintain a force's level of effectiveness, airlift sustainment missions provide resupply of equipment, personnel, and supplies. Finally, airlift supports the movement of patients to treatment facilities and noncombatants to safe havens. Airlift's characteristics — speed, flexibility, range, and responsiveness — complement other US mobility assets" (JP 3-17, 2009:IV-1).

JP 3-17 also discusses how the US Army relies on airlift assets in order to accomplish global operations:

> "Even though the Army has significant organic airlift assets, it often has the largest requirement for common-user airlift. Army forces rely heavily on intertheater and intratheater airlift for deployment, airborne operations, and redeployment of personnel and early arriving or departing unit equipment. Sustainment is also moved during deployment, but its delivery must frequently be balanced against force deployment or redeployment requirements because these operations share the same deployment and distribution infrastructure and other resources" (JP 3-17, 2009: IV-10).

The US Army's tendency to "rely heavily on intertheater airlift…for…redeployment of personnel and early arriving or departing unit equipment" paired with the information above discussing the drawdown of US troop levels to 68,000 prior to September 30, 2012

sets the stage for what could be significant airlift requirements posed by the US Army in the coming months. The Air Force agency that will need to support this potential surge in airlift requirement by the US Army is Air Mobility Command, the air arm of USTRANSCOM.

Air Mobility Command is headquartered at Scott Air Force Base, IL. "Air Mobility Command's mission is to provide global air mobility ... right effects, right place, right time" (Air Mobility Command Fact Sheet, 2012). AMC accomplishes this mission though the use of its one numbered air force, sixteen wings, two airlift groups, and several smaller units.

Air Mobility Command operates its missions according to mission types and customer. Although there are many varied mission types, there are basically three large categories: Channel missions, Special Assignment Airlift Missions, and Exercise and Contingency Support missions. Air Force Doctrine Document 3-17 defines these mission types as such:

> "Channel missions…are regularly scheduled taskings flown over fixed routes and AMC uses two types of channel missions to meet operational requirements: requirement-based and frequency-based. A requirement-based channel is established when a specified amount of passengers, patients, or cargo destined for one location warrants movement. A frequency-based channel is established to serve locations with high activity levels or regular sustainment needs. These channels can serve intertheater or intratheater needs. The majority of airlifted sustainment moves on channel missions. Both channel types use DoD transportation movement priority classifications.
>
> SAAMs are operated to satisfy unique operational requirements for pickup and delivery at locations other than those established within the established channel structure. SAAM movements may be driven by constraints on the user, time, geographic location, passenger or patient requirements, or type of cargo. SAAMs are prioritized through the DoD transportation movement priority system.

> Exercise and Contingency Support Exercise and contingency missions involve deployment, sustainment, and redeployment via intertheater or intratheater airlift. Geographic combatant commanders normally develop an operation plan (OPLAN) or operation order (OPORD) with specific logistical requirements for operations directed by the President, the SecDef, or the JCS. Deployment and redeployment transportation requirements are planned using the JOPES. Supported commanders validate their requirements to USTRANSCOM through the TPFDD. The TPFDD details the combatant commander's deployment/redeployment priorities that enable AMC planners to build air movement plans. AMC plans and moves sustainment requirements through the channel system by establishing frequency or requirements channels. Regardless of the method used to identify the requirement, the 18 AF TACC and AMOCC schedule assigned airframes, missions and support necessary to manage the air mobility flow" (AFDD 3-17, 2006: 36).

Based on the above mission sets, US Army Soldiers and any US personnel returning home from Afghanistan will most likely travel on Contingency missions or Channel missions that are already scheduled to transit the required departure points and destinations. This paper will analyze these types of missions and also look at the SAAM mission-types as well to determine savings potential in all three mission sets for this paper's proposal.

Aircraft Calculations

For the purposes of this paper, the author will be focusing on three main types of aircraft costs: fuel costs, variable costs, and operational costs. Operational costs are costs that are accrued directly and indirectly when operating aircraft. According to the Air Force Cost and Performance program provided by AMC FM/FMAO, "Operations and Maintenance (O&M) costs include pay and allowances for military and civilian personnel; unit level consumption; intermediate maintenance (external to the unit); depot maintenance; contractor support; sustaining support, and indirect support" (AFCAP, 2011). Variable costs are a sub-component of operational costs that directly relate to

operating the aircraft (i.e. excludes indirect costs). Variable costs only include those costs related to "Unit Operations" and "Maintenance." See Appendix B for a breakdown of how these costs are distributed (AFCAP, 2011).

The table below provides an overview of the operational and variable costs (VCPFH—Variable Cost Per Flying Hour) of C-17 and C-5 aircraft:

Table 1: C-17 and C-5 Operating and Variable Costs Per Flying Hour

	FY11 Aircraft Total Costs (TY$)	
	C-17	**C-5 A/B/C/M**
TY 1.0 - Mission Personnel	$876,840,081	$568,688,176
TY 2.0 - Unit Level Consumption	$2,287,628,265	$786,696,120
TY 3.0 - Intermediate Maintenance	$0	$0
TY 4.0 - Depot Maintenance	$113,716	$604,404,129
TY 5.0 - Contractor Support	$1,319,205,099	$52,688,368
TY 6.0 - Sustaining Support	$5,567,569	$55,334,349
TY 7.0 - Indirect Support	$103,976,666	$106,702,915
Total Operational Cost	$4,593,331,396	$2,174,514,057
Variable CPFH	**$12,714**	**$27,406**
Fixed CPFH	$8,108	$30,528
Hours-Total	220,600	37,535
Operational Cost per Flying Hour	**$20,822**	**$57,934**

Source: AFCAP Ver5.7 based on AFTOC FY11Q4 release

Based on the above information, the operational costs used in this paper will be **$20,822/flying hour** for the C-17 aircraft and **$57,934/flying hour** for the C-5 aircraft (all variants) and variable costs for each aircraft will be **$12,714 and $27,406** respectively.

Fuel costs are encompassed within the Unit Level Consumption figure of the above chart and are a major part of an aircraft's operational and variable costs. As stated earlier, the Air Force accounts for 64% of all fuel expenditures by the Armed Services.

Based on this fact, the Secretary of the Air Force has set a goal to reduce aviation fuel consumption by 10% by 2015 against an FY2006 baseline (AF Energy Plan, 2010:8). Tracking fuel usage rates and savings (where applicable) is necessary in order for Air Mobility Command to satisfy this goal set by SECAF. Based on this information, gathering and identifying fuel savings and the cost avoidance generated within this project is merited.

The author determined two types of fuel costs in his calculations: Flying Fuel Costs and Total Fuel Costs. Flying fuel costs were derived from the 2011 Fuel Cost/Gallon AFCAP figures and an AMC Fuel Management Office-provided value for each aircraft's fuel burn. Total Fuel Costs in this paper were determined by adding an APU fuel cost value to the Flying Fuel Total. Table 2 below provides an overview of these figures:

Table 2: C-17/C-5 Fuel Usage Rates

	C-17	**C-5**
Fuel lbs/gallon	6.76	6.76
Fuel Cost/gallon[1]	$ 3.41	$ 3.41
Fuel Burn/hr (G)[2]	2776	3529
Fuel Burn/hr (lbs)	18599.2	23644.3
Flying Fuel Cost/Hr	**$ 9,466.16**	**$ 12,033.89**
APU lbs/gallon	6.76	6.76
Fuel Cost/gallon[1]	$ 3.41	$ 3.41
APU Fuel Burn/hr (G)[2]	62.10	44.4
APU Fuel Burn/hr (lbs)[2]	419.796	300.144
APU Cost/hr	$ 211.76	$ 151.40
C-5 Second APU[3]	--	$ 151.40
Total Cost/hr	**$ 9,677.92**	**$ 12,185.29**

1 - Source: AFCAP Version 5.6

2 - Source: AMC/Fuel Efficiency Office

3 - C-5 aircraft use two APUs during operations

Another calculation utilized in this paper is that of flying hours and mission hours. Flying hours were calculated using an aircraft's flight time for each applicable leg in the calculations. Mission hours were determined using standard ground times found in *AMCI 10-202V6, Mission Management and Reliability Reporting System (MMRRS).* See Table 3 below.

Table 3: C-17/C-5 En Route Ground Times

	C-17	**C-5**
Refuel Only	1 + 45	2 + 45
Onload/Offload/Refuel	2 + 45	3 + 45

Source: AMCI 10-202V6, 15 Mar 2011

An Overview of Transportation Modes

For this paper, three modes of travel are discussed: air, rail, and truck. There are distinct advantages and disadvantages for each form of transportation and these characteristics generally affect the type of transportation a consumer chooses depending on that consumer's needs.

Air transportation is often the highest speed, highest cost mode of travel. The operating costs of aircraft are mainly dominated by two main factors: fuel and labor costs. The price of fuel strongly affects an airline's profitability and as the price of fuel increases, the chance of an airline's profitability drastically decreases. Based on these characteristics, aircraft are used to ship freight mainly when time is of the essence. Items generally shipped by air include: emergency shipments and typical commodities (mail, fashion clothing, communications products, fresh flowers, racehorses, jewelry) (Coyle, 2011: 226-249).

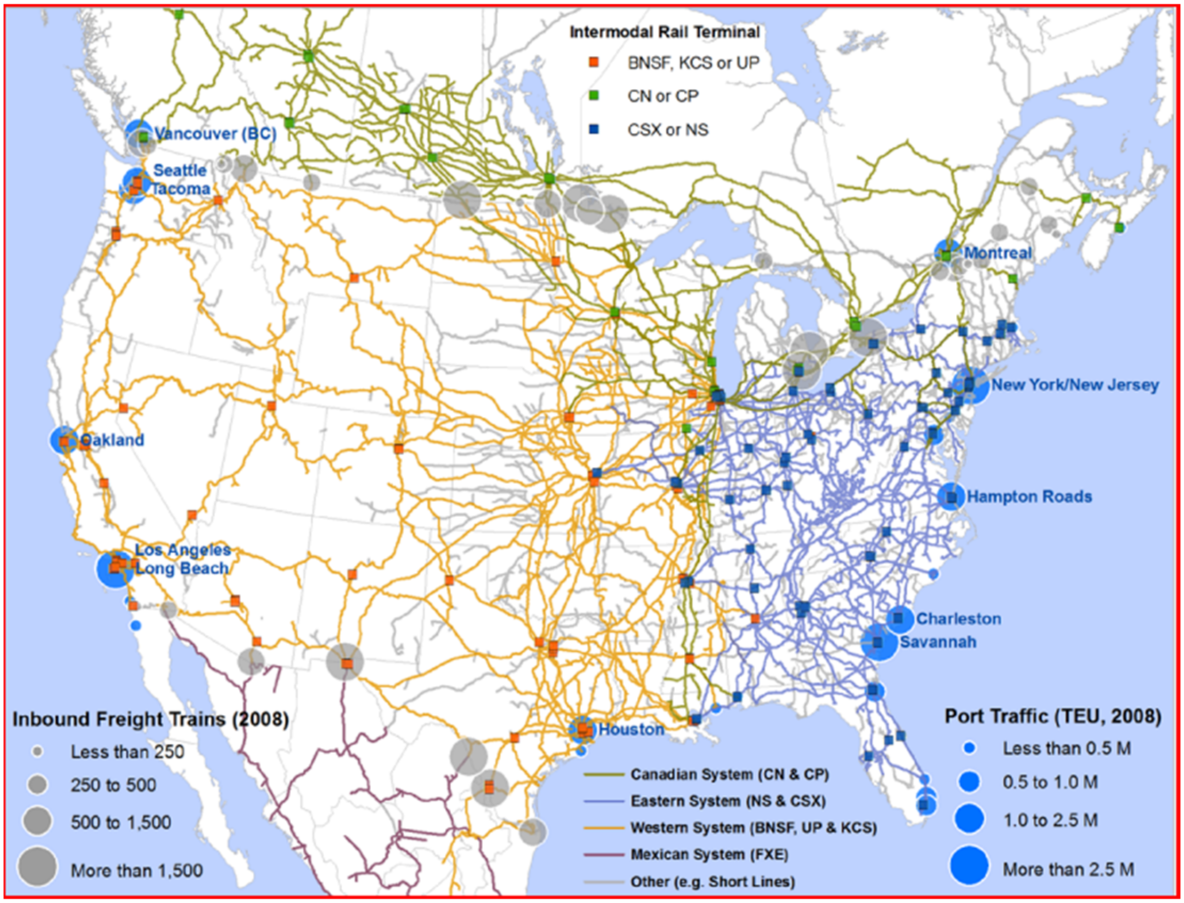
The US Air Force operates most of the US Military's fixed wing (i.e. non-helicopter) air assets. Air Mobility Command operates over 1300 aircraft on its mission around the world as the haulers of US military "freight." The US Air Force capably uses its unique abilities to rapidly project its forces around the world within days and sometimes hours of a crisis. However, the US Air Force also, at times, utilizes its aircraft to transport cargo when other, less-costly means are available and the cargo in question is not necessarily time-sensitive (i.e. redeployment). In some cases, this type of transport is necessary due to the nature of the cargo (hazardous, classified, ammunition, etc.) and the fact that the cargo cannot be easily transported via rail and/or truck. But there could be other times when opportunities exist to cross-load cargo at Aerial Points of Debarkation

(i.e. airports) from airplanes to trucks or containers for rail transport. This paper discusses such scenarios and opportunities for Air Mobility Command and USTRANSCOM and the potential savings that could result from a change in current practices.

Rail transportation is widely considered to be the most economical transport method due to its low level of fuel consumption and the huge capacity of rail cars. According to Dr. Jean-Paul Rodrigue, in *The Geography of Transport Systems*, "Freight traffic is dominated by bulk cargo shipments, agricultural and industrial raw materials in particular. Rail transport is a 'green' system, in that its consumption of energy per unit load per km is lower than road modes" (Rodrigue, 2009). Rail transport also has several other advantages including: Fast delivery, Capacity, Cost effective(ness), Safe mode of transport, Reliable, and Ideal for heavy goods (CORD, 2012).

However, rail transport has several disadvantages which do not lend freight to being an ideal transport system. These include: Potential of damages from shunting, Potential for unforeseen delays, Reliance on rail freight operator's timetable, Suppliers/customers not always located near a rail freight depot and delivery to/from the depot can be costly and time consuming, Limited routes, and Inflexible routes and timetables (CORD, 2012). The feasibility of utilizing rail transport for freight between destinations is highly dependent on whether or not the departure point or destination has a railhead close by. Railheads are the points in which the railway terminates, either at a departure location or at a location where other shipping modes are readily available for further transport.

The following figure below shows the availability of rail lines throughout the United States and where some of the major rail terminals are located:



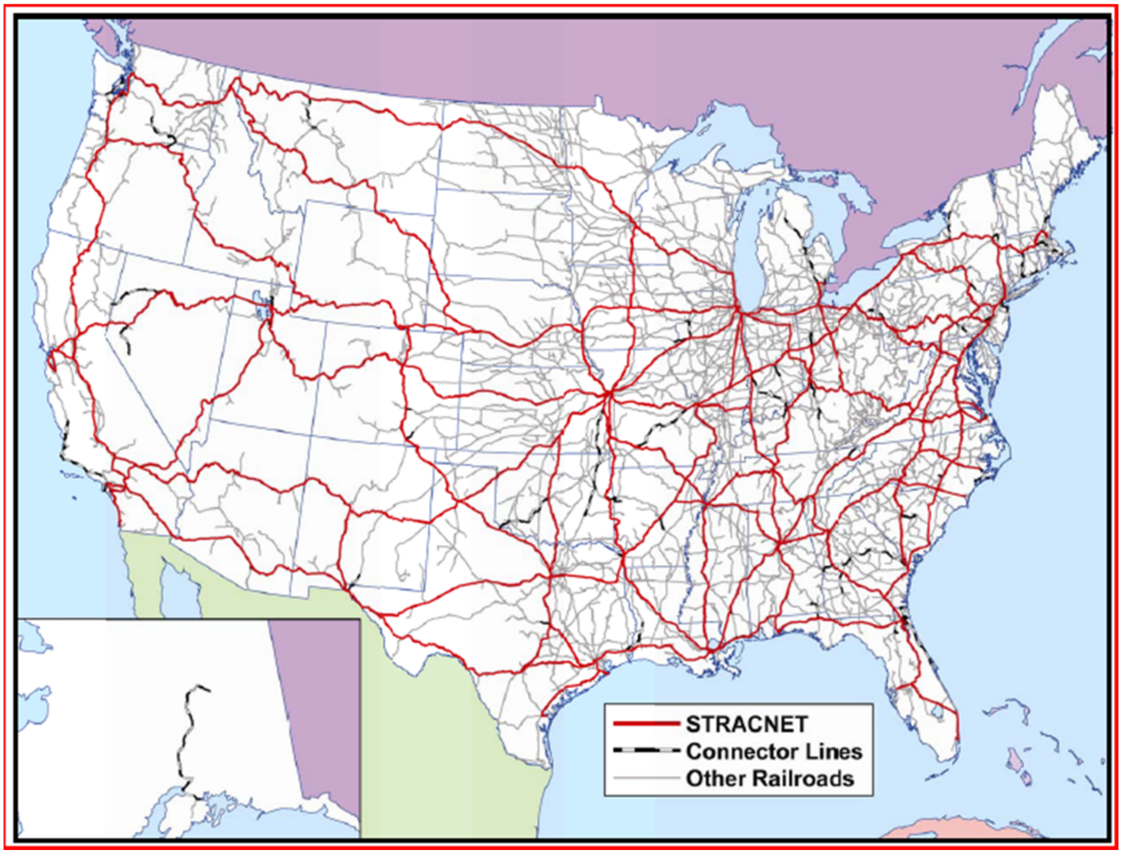
Source: The Geography of Transport Systems, Second Edition

Figure 2: Rail Lines and Terminals in the United States

The US military does maintain some railheads at its military bases. However, the feasibility of utilizing them depends on the maintenance and caretaking of these railheads. Some military installations are active in their use of their railheads and maintain them in good working order while others have outdated railheads that need updating prior to any extensive use. In those cases where military bases do not have their own dedicated railhead, there is often a railhead within a reasonable transport distance by

truck. Appendix A contains a state-by-state listing of those military installations that require a railhead on base or one that is accessible nearby.

The US Government also maintains an active interest in maintaining the US rail network for its strategic defense. In 1975, the US government established the Railroads for National Defense Program to ensure that the US military's railroad needs were met. "The purpose of the RND Program is to identify defense rail requirements; assure consideration for national defense in civil railroad policy, plans, standards, and programs; and gain support and responsiveness for defense rail line requirements" (HQ SDDC, 2008: 5). While the US government does not actively maintain these lines, the government ensures that railroad bankruptcies, disruptions in service, etc. do not adversely impact National Defense. The US government does this by designating those rail lines that are most important to US interests and identifying them as being key components of what is called STRACNET. STRACNET is the Strategic Rail Corridor Network for the US government. Rail lines that fail due to economic reasons or based on mechanical/aging issues are assessed regarding their impact to STRACNET. If other corridors can be used while maintaining the integrity of STRACNET, then the rail lines can be shut down. If not, then the US government may provide assistance to ensure the integrity of STRACNET is maintained. A diagram of the STRACNET system of railroad corridors is shown below in Figure 3.



Source: Strategic Rail Corridor Network (STRACNET) and Defense Connector Lines

Figure 3: STRACNET & Other Important National Defense Rail Lines

The final mode of transport addressed in this paper is that of truck transportation. Truck transportation is the most accessible and flexible mode of transport among the three. Trucking as a whole offers a "door-to-door"-like service for its wares that other modes of transportation cannot attain in all cases (in some situations, the other modes may be able to achieve a similar result but not to the extent that trucking can attain). Other advantages of trucking include: Fast delivery, Ideal for short distances, Ideal for transporting perishables (i.e. fruit and vegetables)**,** Easy to monitor location of

goods, Easy to communicate with driver, and Ideal for sending by courier shortages to customers (CORD, 2012).

Some disadvantages of trucking include rules and regulations that may hamper delivery timelines, weather and traffic delays, and trucks that may suffer mechanical breakdowns en route.

The US military often takes great advantage of the accessibility and flexibility of trucking to satisfy its military needs. Trucks are utilized to transport military equipment and vehicles from base-to-base, base-to-airport, and base-to-seaport for deployments and in some cases redeployments.

The importance of maintaining a viable roadway infrastructure within the United States for National Defense needs is monitored via the Strategic Highway Network (STRAHNET) much like the STRACNET of the US railroad system. According to Military Surface Deployment and Distribution Command, "STRAHNET is a system of about 61,000 miles of highways, including the Interstate System. An additional 2,000 miles of STRAHNET Connectors link important military installations and ports. Together, STRAHNET and the Connectors define the total minimum public highway network necessary to support Defense deployment needs" (MSDDCTEA, 2012). A figure of STRAHNET is provided in Figure 4 below.

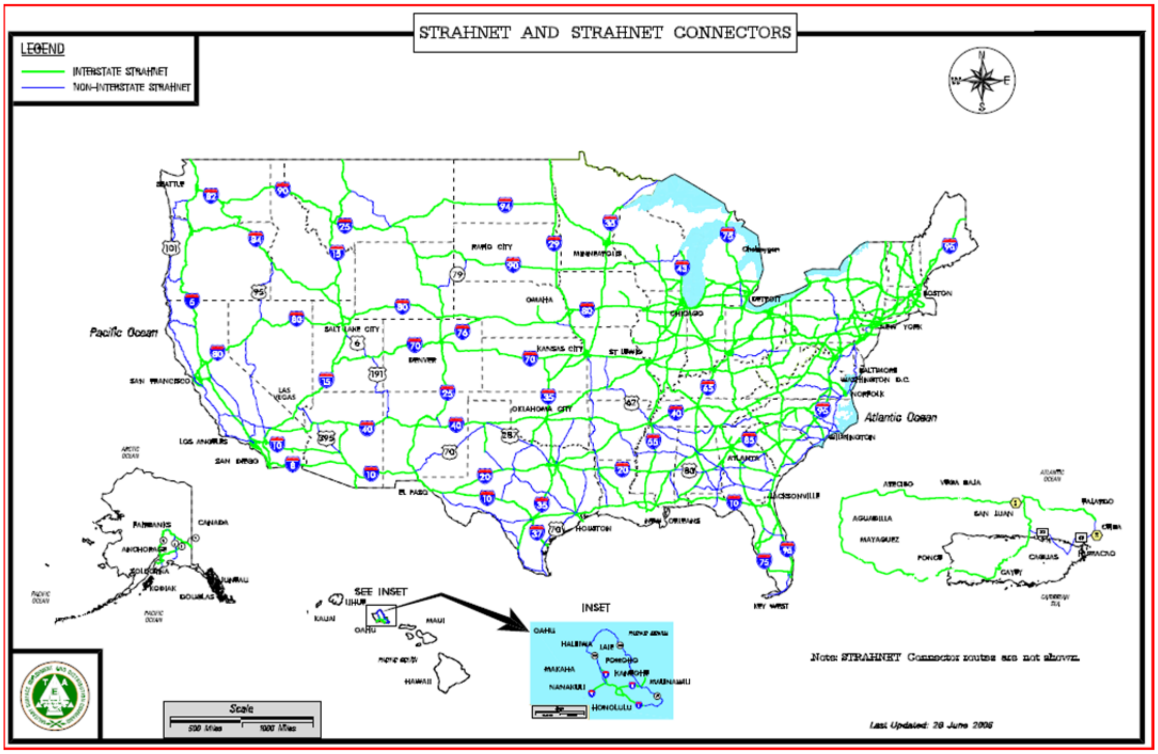


Figure 4: Strategic Highway Network (STRAHNET)

The three modes addressed in this paper (air, rail, truck) each have distinct characteristics, advantages, and disadvantages in their use. The below table sums up each according to mode.

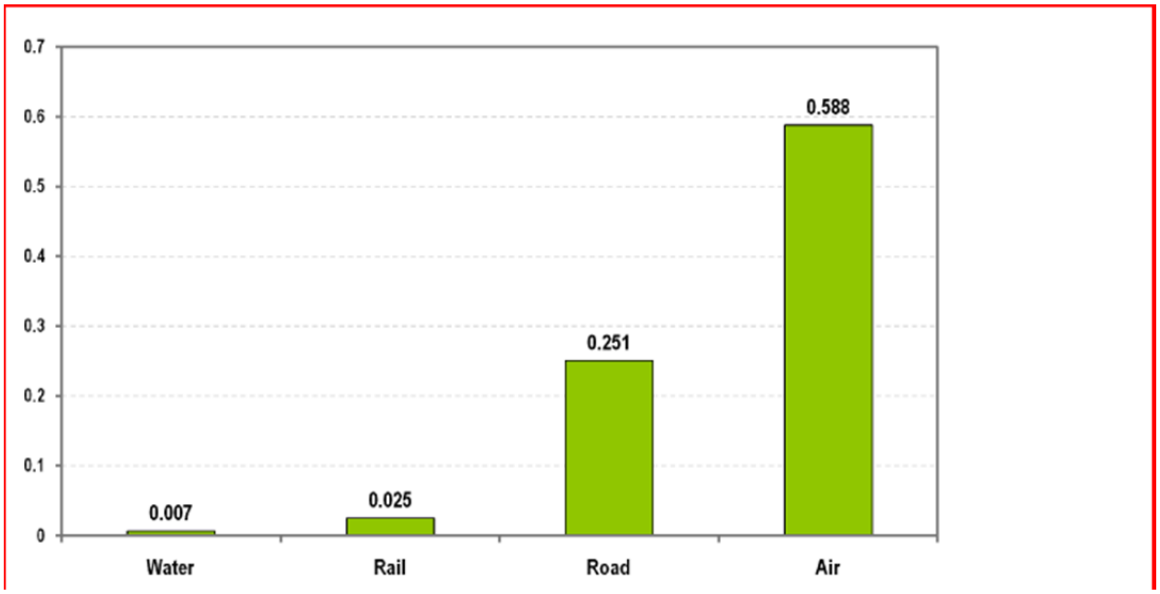
Table 4: Characteristics of Air, Truck and Rail Transport

Characteristics	AIR	TRUCKS (LAND)	RAIL
Accessibility	Moderate	High	Moderate; Customer not always near rail
Capacity	Very Low	Low	Moderate
Commonly used for:	Goods from distant suppliers; products in high demand or short supply; fragile and non-bulky goods	Virtually any product; ideal for perishables	Bulk commodities such as grain and coal
Consistency (Delivery Time Variability)	High	Moderate	Moderate
Cost	Very High	Moderate	Low, less than air or motor carrier
Flexibility (Adjustment to Shipper Needs)	Moderate	High	Moderate Limited to fixed tracks
***Intermodal Capability**	Moderate	Very High	Very High
Lead Time	Short	Short to Moderate	Long
Monitoring Capability	Easy	Easy	Moderate
Risk of Loss and Damage	Low	Low	Moderate
Safety	Generally safe	Generally safe	Generally safe; good mode for hazardous materials
Speed (Time in-Transit)	Fast	Moderate to fast	Slow to Moderate

***Intermodal freight transport involves the transportation of freight in a container or vehicle, using multiple modes of transportation (rail, ship, and truck), without any handling of the freight itself when changing modes.**

Source: CORD, Stem Transitions. "Ratings of Transportation Characteristics" (2012)

The last dimension to discuss in this overview of transportation modes is that of cost. A generalized comparison of costs between the three modes of travel in cents per Ton-Mile traveled is below. For reference, a Ton-Mile is simply defined as moving a ton of freight one mile.



Source: Rodrigue, J-P, C. Comtois and B. Slack (2009), The Geography of Transport Systems, Second Edition, New York: Routledge. Adapted from R. Ballou (1998) Business Logistics Management, 4th Edition, Upper Saddle River, NJ: Prentice Hall. 11 Apr 2012.

Figure 5: Comparison of Transport Costs ($ / Ton-Mile)

As evidenced by the above chart, the cost of rail transport is significantly less than road and air transport while air transport remains far and away the most costly means of transportation. The vast difference between the pricing of air freight and that of the other methods comes down to an airline's operating costs: mainly fuel and labor. Due to the high cost of jet fuel and the significant amount of fuel that an aircraft uses in transporting cargo between two points, the costs of that fuel are rolled into the price of their offered services. Road and especially rail use significantly less fuel and are able to offer cargo transport at a much lower rate.

The Department of Defense and the US Air Force are not exempted from paying a high cost when it comes to utilizing air transport versus rail and/or truck. As mentioned earlier, a significant amount of the DoD budget covers just the fuel costs for the US Air Force to operate its aircraft. Significant savings can be garnered for the US government by reducing this fuel usage in changes to how and when the US Air Force operates its aircraft.

Summary

This Literature Review touched upon many factors that will affect Air Mobility Command and USTRANSCOM decision-makers in the coming months. The drawdown of 23,000 additional troops and their equipment from Afghanistan before October 2012 will put significant requirements on AMC and USTRANSCOM to effectively and efficiently redeploy these personnel and equipment while minimizing operating costs and hours.

AMC will operate several types of missions in order to transport these personnel and their equipment home. A brief discussion on the differences between Contingency, Channel, and SAAM missions explained the differences between these missions.

Aircraft operating, variable, and fuel costs were discussed to gain a basic understanding of the cost of performing AMC missions.

An overview of transportation modes and a generalized look at their costs was then discussed to provide a broad picture perspective as to the varying advantages, disadvantages, and costs of utilizing specific modes of transport.

III. Methodology

Chapter Overview

This section delves into the methodology that the author used in order to prove or disprove the hypothesis that utilizing a multi-modal approach for cargo transport from West/East Coast bases rather than flying operations will provide significant savings in operational, variable, and fuel costs. The author decided on a case study approach focusing on C-17 and C-5 missions that operated from 1 Jul 2011 – 30 Sep 2011 to analyze for cost-savings opportunities utilizing a multi-modal approach. Using these missions, the author identified "opportunities" for savings and calculated the operational, variable, and fuel costs of operating these missions. The author then calculated the cost of utilizing a multi-modal approach to move the cargo from a West/East Coast base vice flying it in aircraft to determine the overall savings.

Case Study

The data selected for study (1 Jul 2011 – 30 Sep 2011) contains many of the missions that were utilized by the Department of Defense for the initial drawdown of US troops from Afghanistan mentioned earlier. 10,000 US troops and their equipment in some cases traveled home prior to the end of 2011 via military transport with a good portion being on AMC airplanes. An additional 23,000 troops and equipment will have to make the same journey prior to the end of 2012 to meet President Obama's mandate of removing 30,000 US troops by September 2012. By analyzing the AMC missions that occurred during the initial troop drawdown in the 3rd Quarter of 2011, this case study can

draw conclusions as to how the future withdrawal may utilize AMC aircraft and how AMC and USTRANSCOM planners can realize savings by adjusting their operations.

Methodology Overview

The information below is a big-picture overview of the methodology that the author used in calculating the cost difference between air and ground transport. More details on the calculations themselves are located two sub-sections below in the Calculation section. The actual calculation spreadsheet is also available upon request from Dr. William Cunningham, at the Air Force Institute of Technology.

Data for AMC missions was provided by AMC/A9 based on 618 Air and Space Operations Center (618 AOC (TACC)) missions that were flown between 17 May 2011 – 28 Oct 2011. This data contained all those missions flown by C-5 and C-17 aircraft during this time to include Contingency, Channel, SAAM, and Training missions. C-5 and C-17 aircraft are the sole focus of this study based on the fact that these types of aircraft provide AMC's strategic capability and this global transport is their primary mission. In some cases, cargo may be transported on other aircraft (KC-10, C-130, etc.) however, the majority of cargo transported by AMC is via C-17 and C-5 aircraft therefore that is the focus of the author in this case study. Next, the author eliminated all the Training sorties that were not operational missions to limit the number of missions being studied. This approach is valid since almost all Training missions are flown without user cargo and do not apply to this case study. The author then adjusted the timeframe to the 3rd quarter of 2011 to have a representative sample of missions that could be easily used to estimate a year's worth of data.

Based on this data, the author further narrowed the missions in the 3rd quarter, 2011, to account for the hypothesis of the proposal. In order to do this, the author decided to focus on missions that were returning from Europe to CONUS bases, eliminating those few missions that are able to travel direct from theater to CONUS via aerial refueling. As such, the author identified three bases in Europe that are routinely used as primary departure points for C-17 and C-5 aircraft returning to CONUS. These bases are ETAR (Ramstein Air Base, Germany), ETAD (Spangdahlem Air Base, Germany) and LERT (Rota Air Base, Spain). Based on the amount of cargo being carried by these returning aircraft, there are also bases en route from Europe to CONUS that are required as fuel stop locations. These locations are CYQX (Gander International Airport, Canada) and KBGR (Bangor Air Force Base, Maine). These locations were also included as part of the sample model as departure points for aircraft arriving into CONUS.

The CONUS arrival bases consisted of the home stations of the operating aircraft as well as the cargo destination airfields. The following airfields were analyzed in the model: KWRI (Joint Base McGuire-Dix-Lakehurst, NJ), KDOV (Dover Air Force Base, DE), KCHS (Joint Base Charleston, SC), KPOB (Pope Army Airfield, NC), KHOP (Campbell Army Airfield, KY), KGRK (Robert Gray Airfield, TX), KBIF (Biggs Army Airfield, TX), KGRF (Gray Army Airfield, WA), KTCM (Joint Base Lewis-McChord, WA), KSUU (Travis Air Force Base, CA), KRIV (March Air Reserve Base, CA), KVPS (Eglin Air Force Base, FL), KSVN (Hunter Army Airfield, GA) and KNZY (Naval Air Station North Island, CA).

The author also focused only on aircraft home stations that will most likely be able to support additional cargo requirements (offloading and readying for truck/rail travel) and eliminated those bases that in all likelihood would not be capable. The airfields mentioned above include those destinations that the author deemed most capable at supporting increased offload requirements. The aircraft home stations that were eliminated based on limited cargo offload capability includes: KJAN (Jackson Air National Guard Base, MS), KMRB (Martinsburg Field, WV), KSWF (Stewart Air National Guard Base, NY), KCEF (Westover Air Reserve Base, MA), KMEM (Memphis Air National Guard Base, TN) and KFFO (Wright Patterson Air Force Base, OH). Additionally, aircraft home stations that were outside of CONUS (PAED – Joint Base Elmendorf-Richardson, AK and PHIK – Joint Base Pearl Harbor-Hickam, HI) were eliminated from the model.

Based on the above parameters, a sample size of 1439 missions were assessed for situations in which multi-modal transport may save aircraft operational and variable costs as well as fuel costs. The author performed an analysis of each aircraft separately and then combined the results at the end to have a C-17/C-5 combined result.

C-17 aircraft were analyzed in their missions returning from theater by way of ETAR and ETAD airfields in Germany. Some of these aircraft have extended range capability based on their configurations and are capable of traveling directly from ETAR/ETAD to East Coast bases. The C-17s without the extended range tanks typically have to stop at CYQX or KBGR for a fuel stop prior to proceeding to their next destination when departing from ETAR/ETAD.

In examining the C-17 missions in the sample set, the author determined four types of missions that presented opportunities for savings. The author coined the following terms for these missions: Boomerangs, Leapfrogs, Maine-iacs, and Paratroops. A Boomerang mission consists of a C-17 that overflies its home station in order to deliver cargo to an inland destination and then returns back to its home station. An example of such a mission is a C-17 that flies from CYQX (Gander, Canada) to KHOP (Campbell Army Airfield, Kentucky) and then back to its home station of KWRI (Joint Base McGuire-Dix-Lakehurst, New Jersey). This paper proposes that a better approach to a mission of this type would be for the aircraft to proceed from CYQX to its destination of KWRI, eliminating the stop at KHOP. The cargo that was scheduled to travel to KHOP via air would instead be offloaded at KWRI and shipped via truck and/or rail to KHOP.

Another opportunity for savings is that of a Leapfrog mission. The author identified a Leapfrog mission as a mission when a plane proceeds well out of its homeward path in order to deliver cargo to an inland base rather than dropping the cargo off at an East/West Coast base for ground transport. An example is that of a KTCM (Joint Base Lewis-McChord)-assigned aircraft landing at KWRI (Joint Base McGuire-Dix-Lakehurst) from Europe, proceeding to KGRK (Robert Gray Airfield, TX), then proceeding home to KTCM. Rather than flying this additional leg, the author proposes that the aircraft could offload cargo at KWRI for truck/rail transport to KGRK, thus allowing the aircraft to fly directly to KTCM and eliminate the intermediate stop.

The Maine-iac missions are another example of opportunities for saving according to the author. These missions entail using aircraft that are capable of proceeding from ETAR/ETAD directly to KWRI without a fuel stop in Bangor, ME

(KBGR). The aircraft would then offload their cargo at KWRI for future transport via truck/rail prior to the aircraft flying direct to its home station. An example of this route is an aircraft that flew from ETAR-KBGR-KHOP-KTCM. Rather than flying this route, the aircraft would instead fly from ETAR-KWRI-KTCM, eliminating the stop at KHOP by offloading its cargo at KWRI for ground transport.

The last type of C-17 mission that the author analyzed was that of the Paratroop missions. These missions consist of Charleston-assigned C-17s that flew from CYQX/ETAR/ETAD to KHOP or KPOB and then to KCHS. The author proposes that these tails could fly from CYQX/ETAR/ETAD direct to KCHS for cargo offload and eliminate the intermediate stop. This flight route would most likely require extended-range aircraft be utilized on the flights departing from ETAR and ETAD.

For C-5 missions, the author examined the data for similar flight routes that would present savings opportunities. The same types of missions (Boomerangs, Leapfrogs, and Maine-iacs) were discovered and analyzed for savings.

The author identified fifty (50) C-17 and C-5 missions that presented opportunities for savings based on the categories identified above. There were forty four (44) C-17 missions and six (6) C-5 missions that could potentially lead to cost savings based on the proposal presented in this paper. For the purposes of this case study, the author focused on these fifty missions for further calculation and case study to determine a representative quarterly average.

The author then calculated the costs of these routes and compared that to the flying costs of the proposed routing. The costs of the routes were broken down into four types: flying fuel costs, total fuel costs, variable, and operational costs. Flying fuel costs

were calculated by determining the flight time each aircraft logged on the flown route multiplied by the average fuel consumption rate of the aircraft. Total fuel costs were calculated by adding in the APU fuel usage for the times that the aircraft were at intermediate stops for cargo offload or refueling (that otherwise would be eliminated by the new routings). Operational costs consist of all the factors (direct and indirect) required to operate aircraft while variable costs relate directly to the operating of aircraft comprising only of unit operations and maintenance costs. Flying fuel and total fuel costs are two variables encompassed within an aircraft's operational and variable costs. However, for the purposes of this paper, the flying fuel and total fuel costs are indicated separately since DoD policy is to eliminate fuel usage whenever possible and having this metric indicated in the proposal shows where fuel usage and costs can be significantly reduced.

In addition to calculating the costs (fuel, operational, and variable) of flying the new routes as opposed to those routes flown in the 3rd Quarter, 2011, the author also calculated the flying hours and mission hours that would be saved on the aircraft (and aircrews) by following the proposal of the paper. This would allow aircraft to return home earlier, saving wear-and-tear on engines and other aircraft parts, and allowing the aircraft and aircrew who have returned earlier to depart on other AMC missions.

The author then determined the ground transport costs of moving the cargo from the download bases to the cargo's ultimate inland destinations. In order to calculate this value, the author first determined the amount of cargo that was to be offloaded at East/West Coast bases by adding up the cargo amounts on the applicable missions.

This cargo consisted of various types of cargo to include rolling stock and pallets and varying weights. The author attempted to use GATES (Global Air Transportation Execution System) in order to find specific cargo information for each applicable mission number but most of the cargo information in GATES for the applicable missions was either missing or incomplete. As a result, the author decided to determine what an average offload consisted of at the inland cargo destinations based on historical data. Using data available from GATES from all C-17 and C-5 missions that offloaded cargo at the applicable destinations from the period October 2010 – December 2011, the author was able to determine an average cargo offload for an aircraft at each location based on total weight, number and weight of pallets, and number and weight of rolling stock. Using this information, the author was able to calculate the expected types of cargo of the applicable missions to be offloaded at each destination by dividing the weight of cargo at each offload destination by the average historical figure.

Using this information, the author determined what a typical C-17 or C-5 sortie into each location would carry based on the actual weights of the selected missions. The author then determined what it would cost to transport each aircraft load via truck and/or rail to each inland destination. If there was more than one aircraft sortie into the same location, the load was assumed to be the same weight and configuration and the sortie's cost was multiplied out to match the number of sorties flown.

Trucking costs were divided into two types of cargo loads: Less-Than-Truckload/Flatbed (LTL/Flatbed) and Truckload/Less-Than-Truckload/Flatbed (TL/LTL/Flatbed). The Less-Than-Truckload option assumes that each set of cargo is traveling piecemeal to its destination and not able to aggregate enough to fill a Truckload.

The Truckload/Less-Than-Truckload option transports each 25,000 lbs of cargo as a Truckload and then transports the remaining cargo via LTL. Both options utilize Flatbed trucks for their rolling stock cargo transport. One Flatbed trailer was used to transport up to 25,000 lbs of rolling stock cargo. Any fraction above 25,000 lbs would require an additional Flatbed trailer for transport.

Trucking costs for TL/LTL/Flatbed transport were provided by SDDC (Morgan, 2012) for the varying departure and arrival locations. The cargo was assumed to be freight of all kinds (FAK) and costs were based on a standardized pallet utilizing the average calculated for each destination from the GATES historical data.

Rail costs were determined using a historical rate for rail transport based on Ton-Mile transported. The distance between East/West Coast bases and the inland destinations was determined using Google Maps and the author assumed that the distances covered by rail would be similar to those by road. The amount of cargo transported from each East/West Coast base was then multiplied by the Ton-Mile historical figure to determine an associated cost for transport of the cargo via rail.

Assumptions/Limitations

In order to limit the multitudes of possibilities between aircraft, cargo loads, arrival/destination airports, etc., certain assumptions and limitations had to be made for this case study. Actual figures were taken from published sources wherever possible in determining any of the below calculations. If a published figure was unable to attain, interviews of Subject Matter Experts were conducted and their inputs treated as facts. In all cases, the source of the data will be annotated.

The author also made other assumptions in order to restrict the scope of the case study so that it didn't include all possible combinations of scenarios and become prohibitively large. Some of these assumptions include: the missions identified had no other priority reasons (such as passengers, ammunition, hazardous material, etc.) to preclude them from dropping their cargo off at West/East Coast bases. The author also assumed standard weather days for all aircraft when coming over from Europe (i.e. no fuel wasted avoiding thunderstorms that could necessitate an additional fuel stop). It is also assumed that all aircraft burn their fuel based on the average amount of gallons burned per hour provided by the AMC Fuel Efficiency Office. Extended Range C-17s were assumed to be available and utilized for the Maine-iac and Paratroop missions. C-5 aircraft were assumed to be able to fly from LERT to KDOV with their cargo load on the selected missions.

Various assumptions about the cargo itself were necessary as well. As mentioned above in the Methodology Overview, the cargo loads were given in weight transported but no information as to type of cargo onboard each aircraft was provided to the author. Therefore, the author calculated the average cargo load (weight and type) into the inland cargo destinations based on historical data and used this information to determine what an expected cargo load aboard each plane was based on cargo weight. This expected cargo load was offloaded at the West/East Coast base and transported via ground transport.

The author also assumed the following for the truck transport of the cargo: the cost to transport a pallet of cargo was based on the historical weight of pallets into each inland destination. For example, if it was determined that pallets going into KBIF

historically weighed 3,000 lbs apiece, then the transport costs for 8 pallets will be based on eight 3,000 lb pallets from the West/East Coast base to KBIF. Also, a Truckload is determined to be 25,000 lbs of cargo, no matter the number of pallets (i.e. ten 2,500 lb pallets or two 12,500 lb pallets). In the TL/LTL/Flatbed option, it is assumed that Truckloads are utilized where able and LTL is utilized for the remainder. For Flatbeds, the author assumed that the number of Flatbeds required is based on weight. One Flatbed is assumed to be required for each 25,000 lbs of cargo. If the weight of the rolling stock cargo exceeded 25,000 lbs, then an additional Flatbed was required even if it was only slightly exceeded. For example, if the weight of the rolling stock was 26,000 lbs, then two Flatbeds were required.

Assumptions were also required for the rail transport option. It is assumed that the cargo transported by rail is easily transferrable from the aircraft to the rail station with no reconfiguration. The author is also assuming that the rail cars are ready and available for transportation with no demurrage or waiting on cargo for transport. The cost of transporting the rail is based on the historical cost of transporting cargo via rail in cents per Ton-Mile. Also, certain assumptions about the capabilities of both the departure location (West/East Coast base) and the inland arrival destination are warranted. In computing the costs of transporting the cargo to the inland destinations, the author assumed that both the departure airfield and arrival base are capable of handing the rail cargo. However, the analysis section of this paper will contain a more detailed discussion about the actual capability of the rail cargo option at the various bases.

Calculation Examples

Flying Costs

In order to calculate the operational costs, variable costs, fuel costs, flying hours, and mission hours of missions, the author used standardized figures provided by various sources. Table 5 below details the operational and fuel costs of C-17 and C-5 aircraft:

Table 5: Flying Calculation Figures

	C-17	C-5
Operational Cost/Flying Hour (CPFH)[1]	**$ 20,822.00**	**$ 57,934.00**
Variable Cost/Flying Hour[1]	**$ 12,714.00**	**$ 27,406.00**

	C-17	C-5
Fuel lbs/gallon	6.76	6.76
Fuel Cost/gallon[2]	$ 3.41	$ 3.41
Fuel Burn/hr (G)[3]	2776	3529
Fuel Burn/hr (lbs)	18765.76	23856.04
Flying Fuel Cost/Hr	**$ 9,466.16**	**$ 12,033.89**
APU lbs/gallon	6.76	6.76
Fuel Cost/gallon[2]	$ 3.41	$ 3.41
APU Fuel Burn/hr (G)[3]	62.10	44.4
APU Fuel Burn/hr (lbs)[3]	419.796	300.144
APU Cost/hr	$ 211.76	$ 151.40
C-5 Second APU[4]	--	$ 151.40
Total Cost/hr	**$ 9,677.92**	**$ 12,185.29**

	C-17	C-5
Refuel Only[5]	1 + 45	2 + 45
Onload/Offload/Refuel[5]	2 + 45	3 + 45

1 - Source: AFCAP Ver5.7 based on AFTOC FY11Q4 release
2 - Source: AFCAP Version 5.6
3 - Source: AMC/Fuel Efficiency Office
4 - C-5s use two APUs during operations
5 - Source: AMCI 10-202V6, 15 Mar 2011

Using the above figures, the author was able to calculate the difference between flying a route with an intermediate cargo stop vice flying an optimized route without the cargo stop that instead dropped cargo off at a West/East Coast base. An example is below:

C-17 Boomerang Example:

Original Route: ETAD-KHOP-KWRI

Modified Route: ETAD-KWRI (Cargo Offload at KWRI for Ground Transport)

ETAD-KHOP-KWRI

Flying Fuel Cost	APU Fuel (Enroute/Fuel Stop)	Total Fuel Cost
$ 111,038.06	$ 423.52	$ 111,461.58

Op Cost	Variable Cost
$ 244,242.06	$ 149,135.22

Mission Hours	Flt Hours
14.48	11.73

ETAD-KWRI

Flying Fuel Cost
$ 84,059.50

Op Cost	Variable Cost
$ 184,899.36	$ 112,900.32

Flt Hours
8.88

Flying Fuel Delta	Op Delta	Variable Delta	Flt Hours Delta	Total Fuel Delta	Mission Hours Delta
$ 26,978.56	$ 59,342.70	$ 36,234.90	2.85	$ 27,402.08	5.6

Figure 6: Flying Calculation Example

The above figures were obtained by multiplying the fuel burned/hour, variable costs/hour and operational costs/hour by the flying time of the aircraft. See equations below:

Equation 1: Flying Fuel Cost Calculation

ETAD-KHOP-KWRI Flying Fuel Cost = Flt Hrs x Flying Fuel Cost/Hour

= 11.73 hours x $9,466.16/hour = $111,038.06

ETAD-KWRI Flying Fuel Cost = Flt Hrs x Flying Fuel Cost/Hour

= 8.88 hours x $9,466.16/hour = $84,059.50

The difference between the two above figures is the fuel saved in dollars and also indicated as the Flying Fuel Delta.

= $111,038.06 - $84,059.50 = $29,978.56

Flight hours in the above equation were determined using the average flight hours on the given leg of aircraft type who had flown the leg from May 2011 – Dec 2011. For those legs in which no sorties had flown to the departure/arrival pairing, TACC's Flight Time Calculator was used. TACC's Flight Time Calculator produces flight times of user-defined routes based on historical aircraft performance data flying the user-input routes or similar routes.

Operational and variable costs in the aircraft are solved in a similar manner except with the Operational Cost/Hour and Variable Cost/Hour of the aircraft substituted for

Flying Fuel Cost/Hour respectively. The Flying Hour difference equation is simply the difference in flying hours between the two missions.

The Total Fuel and Mission Hour calculations involve one other parameter that has not been discussed as of yet: En Route Ground Time. C-17 and C-5 missions that make stops at destinations en route to the aircraft's home station follow a standardized ground time. The standardized ground times for C-17 and C-5 aircraft are detailed in Table 5 above. For the C-17 Boomerang example above, a ground time of 2 + 45 is utilized since the C-17 is offloading cargo at KHOP and refueling prior to returning to KWRI. En Route Ground Time affects Total Fuel calculations since the APU is operating during most of the En Route Ground Time. For the purposes of this paper, the author assumes that the APU is running for all of the En Route Ground Time except 45 minutes (allowing for 15 minutes after landing to turn on the APU and turning it off 30 minutes prior to next takeoff).

The equation for determining Total Fuel Cost is:

Equation 2: Total Fuel Cost

Total Fuel Cost = Flying Fuel Cost + APU Fuel (En Route/Fuel Stop)

APU Fuel (En Route Stop) = 2 hrs x APU Cost/Hr (for C-17s)

APU Fuel (En Route Stop) = 3 hrs x APU Cost/Hr (for C-5s)

APU Fuel (Fuel Stop) = 1 hr x APU Cost/Hr (for C-17s)

APU Fuel (Fuel Stop) = 2 hrs x APU Cost/Hr (for C-5s)

Applying the above equations to the C-17 Boomerang example above yields the following:

Total Fuel Cost = \$111,038.06 + 2 hrs x \$211.76 = \$111,461.58

Mission Hours are determined by adding the Flight Hours to any applicable En Route Ground Time. In the C-17 Boomerang example above, 2.75 Flight Hours (2 hrs + 45 minutes) are added to the Flight Time to give an overall mission time of 14.48 hrs for the ETAD-KHOP-KWRI segments. The ETAD-KWRI option does not have a Mission Hour column since the mission does not have an En Route Ground stop and the mission is completed upon arrival at KWRI. Therefore, the difference between the Mission Hours of the ETAD-KHOP-KWRI profile and the Flight Time of the ETAD-KWRI profile is referred to as the Mission Hours Delta.

Although the above is just one example, the author calculated the potential savings of many C-5 and C-17 missions for this proposal. Overall analysis and conclusions about these calculations will be presented later in this paper. However, if the reader requires greater fidelity, then these calculations can be provided on an Excel Spreadsheet by contacting Dr. Cunningham at AFIT.

Cargo Calculations

The cargo figures provided in the data set included the following key factors: Mission Number, Mission Type, Aircraft Type, Departure Location, Arrival Location, Flight Time, Cargo On/Off Load, Pax On/Off Load, Aircraft Home Base, and Aircraft

Wing. Although there was information presented as to the weights (in STons) of cargo transported and at what station it was on/off loaded, there was little information provided as to what types of cargo was actually being transported. Therefore, the author concluded that a valid approach to estimating the types of cargo transported would be to look at the historical averages from GATES of weights and types of cargo transported into each inland arrival destination. Once this average was determined, the average could be used to infer the type of cargo carried during the case study timeframe (3rd Quarter 2011) in order to determine trucking/rail costs.

Based on the fifty flying missions identified as opportunities for savings, the author identified the applicable APODs and inland cargo destinations for further study regarding the trucking/rail transport costs. The following is the list of APODs and Cargo Destinations identified:

Table 6: APODs/Cargo Destination Listing

APODs	Cargo Destinations
KWRI –McGuire AFB, NJ/Joint Base McGuire-Dix-Lakehurst, NJ (JBMDL)	KPOB – Pope Army Airfield, NC
KDOV-- Dover AFB, DE	KHOP – Campbell Army Airfield, KY
KCHS – Joint Base Charleston, SC	KGRK – Robert Gray Airfield, TX
KTCM—Joint Base Lewis-McChord, WA	KBIF – Biggs Army Airfield, TX
KSUU—Travis AFB, CA	KGRF – Gray Army Airfield, WA
	KVPS – Eglin AFB, FL
	KNZY – North Naval Air Station, CA

The figure below presents the historical figures based on GATES data from October 2010 – December 2011:

	KPOB		KHOP		KGRF	
	Pallets	RS	Pallets	RS	Pallets	RS
# Pieces (Rnded Up)	7	2	10	1	7	2
Weight (in lbs)	4686.8031	6612.3902	5038.9	21691	4500.8333	17352.4
Weight (in STons)	2.3434015	3.3061951	2.51945	10.8455	2.2504167	8.6762
Avg Weight @ Location						
Total Cargo	46032.402		72080		66210.633	
Percentages (Plt vs. Cargo)	71%	29%	70%	30%	48%	52%

	KGRK		KBIF		KVPS		KNZY	
	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS
# Pieces (Rnded Up)	2	3	7	3	5	0	11	1
Weight (in lbs)	4242.44444	13627.135	3567.67	39530	5493	0	1597.03	5432.9
Weight (in STons)	2.12122222	6.81356748	1.78383	19.765	2.7465	0	0.79852	2.71645
Avg Weight @ Location								
Total Cargo	49366.2938		143564		27465		23000.3	
Percentages (Plt vs. Cargo)	17%	83%	17%	83%	100%	0%	76%	24%

Figure 7: Cargo Historical Figures

The above figures represent the average number of pieces of pallets and rolling stock that were transported into these selected arrival stations onboard C-17 and C-5 aircraft during the period October 2010 – December 2011. The average weights of each piece of cargo are denoted as well as the total weight of the cargo (pallets and rolling stock) inbound to the location. Lastly, the percentages of cargo indicate that for an average load of cargo that traveled to a selected destination, X% of that cargo was pallets and the remainder was rolling stock. (For the purposes of this paper, the author eliminated the larger types of pallet trains (i.e. T-3 pallets) for ease of calculations.)

The above figures determine what an average cargo load is per aircraft for selected destinations and the weights of those pieces of cargo. The author then had to determine what the average weight of cargo that was transported per sortie during the Case Study's timeframe.

		Weight/STons	Cargo Final Destination							
		TOTAL	KPOB	KHOP	KSVN	KGRF	KGRK	KBIF	KVPS	KNZY
APOD:	KWRI	**712.23**	322.51	308.62	0		81.1	0	0	
	KDOV	**410.35**	102.4	59	0		185.85	16.8	46.3	
	KCHS	**131.55**	109.55	22	0		0	0	0	0
	KTCM	**106.8**				106.8	0	0		0
	KSUU	**100.795**				19	0	0		81.795
	Total:	***1461.725***	***534.46***	***389.62***	***0***	***125.8***	***266.95***	***16.8***	***46.3***	***81.795***

Cargo Totals for 3rd Quarter, 2011

		Sorties	Cargo Final Destination							
		TOTAL	KPOB	KHOP	KSVN	KGRF	KGRK	KBIF	KVPS	KNZY
APOD:	KWRI	**24**	12	8	0		4	0	0	
	KDOV	**13**	3	2	0		6	1	1	
	KCHS	**6**	5	1	0		0	0	0	0
	KTCM	**4**				4	0	0		0
	KSUU	**3**				1	0	0		2
	Total:	***50***	***20***	***11***	***0***	***5***	***10***	***1***	***1***	***2***

Sortie Totals for 3rd Quarter, 2011

			Cargo Final Destination							
		TOTAL	KPOB	KHOP	KSVN	KGRF	KGRK	KBIF	KVPS	KNZY
	KWRI		26.88	38.58	0.00		20.28	0.00	0.00	
APOD:	KDOV		34.13	29.50	0.00		30.98	16.80	46.30	
	KCHS		21.91	22.00	0.00		0.00	0.00	0.00	0.00
	KTCM					26.70	0.00	0.00		0.00
	KSUU					19.00	0.00	0.00		40.90

Cargo Average/Sortie for 3rd Quarter, 2011

Figure 8: Cargo Totals and Averages, 3rd Quarter, 2011

Next, the author determined the pallet/rolling stock mixture on each aircraft sortie based on the historical percentages of cargo transported into each cargo destination. An example of this calculation is shown below for cargo that was transported from KWRI to KHOP (continuing on the previous C-17 Boomerang example). Full calculations for all airfields and cargo destinations are found in Appendix C.

		KHOP
KWRI		38.58

Cargo Average/Sortie (STons) during 3rd Qtr, 2011

	KHOP	
	Pallets	RS
# Pieces (Rnded Up)	10	1
Avg Weight (in lbs)	5038.900379	21691
Avg Weight (in STons)	2.51945019	10.8455
Total Cargo	72080	
Percentages (Plt vs. Cargo)	70%	30%

Historical Figures for Cargo Arriving KHOP from Oct 2010 – Dec 2011

		KHOP	
		Pallets	RS
KWRI		26.97	11.61

3rd Qtr, 2011, Cargo Breakdown Totals (STons)/Sortie Based on Historical Percentages

		KHOP	
		Pallets	RS
KWRI		53936.78	23218.22

3Q11, Cargo Breakdown Totals (Lbs)/Sortie

		KHOP	
		Pallets	RS
KWRI		10.70	1.07

3Q11, Cargo Breakdown (# of Pallets/RS)/ Sortie

		KHOP	
		Pallets	RS
KWRI		11.00	2.00

3Q11, Rounded Cargo Breakdown (# of Pallets/RS)/Sortie

Figure 9: Aircraft Pallet/Rolling Stock Per Sortie Calculations

Based on the above calculations, the author determined that the expected cargo configuration for aircraft arriving KHOP from KWRI to be: 10.7 pallets (average weight: 5038.9 lbs) and 1.07 pieces of rolling stock (average weight: 21691 lbs).

Similar calculations were competed for each APOD and cargo destination to determine expected aircraft cargo configurations for the fifty identified missions. These calculations ultimately determined the number of pallets and rolling stock that needed to be transported from APODs to cargo destinations via truck/rail.

Trucking Costs

Trucking costs were determined by two different methods as detailed in the overview section. The two methods discussed are: Less-Than-Truckload/Flatbed transport (utilizing both methods) and Truckload/Less-Than-Truckload/Flatbed transport (utilizing all three methods). Considering the method for determining the Flatbed trailers required are the same for both examples, this will be discussed first.

The number of Flatbed trailers required is based on the weight of the rolling stock to be moved. Typically, one Flatbed trailer can move 25,000 lbs of rolling stock. Therefore, the author took the average weight of the rolling stock per sortie and divided by 25,000 lbs to determine how many Flatbed trailers were required. Any fractional number was rounded up to an additional Flatbed trailer. An example of the calculations is provided below using the KWRI-KHOP example as above.

<table>
<tr><td>
<table>
<tr><td></td><td></td><td colspan="2">KHOP</td></tr>
<tr><td></td><td></td><td>Pallets</td><td>RS</td></tr>
<tr><td>KWRI</td><td></td><td>N/A</td><td>23218.22</td></tr>
</table>
</td><td>Rolling Stock Total Pounds/Sortie</td></tr>
<tr><td>
<table>
<tr><td></td><td></td><td colspan="2">KHOP</td></tr>
<tr><td></td><td></td><td>Pallets</td><td>RS</td></tr>
<tr><td>KWRI</td><td></td><td>N/A</td><td>0.93</td></tr>
</table>
</td><td>Rolling Stock Flatbeds Required

(1 req/25K)/ Sortie</td></tr>
<tr><td>
<table>
<tr><td></td><td></td><td colspan="2">KHOP</td></tr>
<tr><td></td><td></td><td>Pallets</td><td>RS</td></tr>
<tr><td>KWRI</td><td></td><td>N/A</td><td>1.00</td></tr>
</table>
</td><td>Rolling Stock Flatbeds Required

(1 req/25K)/ Sortie</td></tr>
</table>

Figure 10: Calculating the Number of Flatbeds Required for Rolling Stock

The cost of transporting equipment was provided by Military Surface Deployment and Distribution Command (Morgan, April 2012). Flatbed rates are located in Figure 11 below.

Routes:		Flatbed***
McGuire	Pope	$669.84
Dover	Pope	$614.25
Charleston	Pope	$519.48
McGuire	Ft Campbell	$1,013.22
Dover	Ft Campbell	$939.51
Charleston	Ft Campbell	$786.35
McGuire	Savannah	$877.50
Dover	Savannah	$860.84
Charleston	Savannah	$519.48
McGuire	Robert Gray (Killeen, TX)	$1,872.00
Dover	Robert Gray (Killeen, TX)	$1,798.29
Charleston	Robert Gray (Killeen, TX)	$1,356.03
McGuire	Ft Bliss, TX	$2,427.75
Dover	Ft Bliss, TX	$2,384.46
Charleston	Ft Bliss, TX	$1,967.94
McChord	Robert Gray (Killeen, TX)	$2,340.00
Travis	Robert Gray (Killeen, TX)	$1,917.34
March	Robert Gray (Killeen, TX)	$1,430.33
McChord	Ft Bliss, TX	$1,999.53
Travis	Ft Bliss, TX	$1,280.05
March	Ft Bliss, TX	$794.14
McChord	Ft Lewis, WA	$456.30
Travis	Ft Lewis, WA	$780.98
March	Ft Lewis, WA	$1,255.91
McGuire	Eglin AFB, FL	$1,271.79
Dover	Eglin AFB, FL	$1,198.08
Charleston	Eglin AFB, FL	$675.31
McChord	North Island NAS, CA	$1,416.87
Travis	North Island NAS, CA	$733.94
Flatbed*** = FAK, 25,000 pounds (flatbed over 40')		

Figure 11: Flatbed Transport Costs

Therefore, continuing the C-17 Boomerang example, the costs of one Flatbed transport from McGuire (KWRI) to Ft Campbell (KHOP) is $1013.22/sortie. Based on the expected cargo numbers calculated above, the amount of rolling stock cargo transported into KHOP per sortie (23,218.22 lbs) can be transported on one Flatbed to KHOP for this price.

In order to calculate the number of LTL shipments, the author used the average historical weight of each pallet to each specific destination as a baseline to determine the

LTL transport costs. LTL rates were provided by Military Surface Deployment and Distribution Command (Morgan, 2012) and are listed in the table below:

	LTL Destinations & Pallet Weights (in lbs)							
	KPOB	KHOP	KGRF	KGRK	KBIF	KVPS	KNZY	
	4687	5039	4501	4242	3568	5493	1597	Average Wt/Pallet
McGuire	$286.07					$635.90		
Dover	$246.87					$599.04		
Charleston	$234.00					$288.41		
McGuire		$506.61						
Dover		$469.76						
Charleston		$346.32						
McGuire								
Dover								
Charleston								
McGuire				$771.28				
Dover				$749.93				
Charleston				$679.77				
McGuire					$724.29			
Dover					$724.29			
Charleston					$657.49			
McChord				$861.11			$333.89	
Travis				$792.11			$223.84	
March				$706.26			$116.78	
McChord					$666.26			
Travis					$574.42			
March					$423.54			
McChord			$238.10					
Travis			$416.52					
March			$669.83					

Figure 12: LTL Rates for Pallet Based On Average Weight

Based on the above information, the cost to transport one pallet (5,039 lbs) between KWRI and KHOP (C-17 Boomerang example) is $506.61. This amount was then multiplied by the number of pallets transported per sortie (11) to equal a total cost for pallet transport of $5,572.71/sortie using LTL transport.

The other method that could be utilized to transport downloaded cargo from East/West Coast bases is that of Truckload/Less-Than-Truckload/Flatbed transport (TL/LTL/Flatbed). The following assumptions are given for such a method:

1) One Truckload of cargo equals 25,000 lbs

2) Cargo from multiple sorties is not aggregated together for TL transport

3) Cargo that is remaining after TLs are filled is transported via LTL transport

The Figure below denotes the rates for Truckload transport between selected departure/arrival locations (Morgan, 2012):

Routes:		TL*
McGuire	Pope	$509.20
Dover	Pope	$488.80
Charleston	Pope	$425.14
McGuire	Ft Campbell	$871.37
Dover	Ft Campbell	$807.98
Charleston	Ft Campbell	$595.67
McGuire	Savannah	$741.57
Dover	Savannah	$643.50
Charleston	Savannah	$409.50
McGuire	Robert Gray (Killeen, TX)	$1,609.92
Dover	Robert Gray (Killeen, TX)	$1,546.53
Charleston	Robert Gray (Killeen, TX)	$1,166.19
McGuire	Ft Bliss, TX	$2,087.87
Dover	Ft Bliss, TX	$2,050.64
Charleston	Ft Bliss, TX	$1,692.43
McChord	Robert Gray (Killeen, TX)	$2,054.05
Travis	Robert Gray (Killeen, TX)	$1,745.31
March	Robert Gray (Killeen, TX)	$1,302.00
McChord	Ft Bliss, TX	$1,679.61
Travis	Ft Bliss, TX	$1,165.20
March	Ft Bliss, TX	$722.89
McChord	Ft Lewis, WA	$403.65
Travis	Ft Lewis, WA	$716.41
March	Ft Lewis, WA	$1,152.10
McGuire	Eglin AFB, FL	$1,271.79
Dover	Eglin AFB, FL	$1,198.08
Charleston	Eglin AFB, FL	$675.31
McChord	North Island NAS, CA	$1,416.87
Travis	North Island NAS, CA	$733.94
TL* = FAK, 25,000 lbs (van, closed over 40')		

Figure 13: Truckload Transport Rates

In order to determine the number of truckloads required per sortie, the total weight of pallets per sortie was divided by 25,000 lbs. For each 25,000 lbs, a Truckload was required and the remainder went as LTL pallets. The figure below denotes these calculations for the C-17 Boomerang example:

		KHOP	
		Pallets (by TL)	RS (by Flatbed)
KWRI		2.16	NA

Number of Truckloads Required = Total Weight of Pallets/Sortie / 25,000 lbs

		KHOP	
		Pallets (by TL)	RS (by Flatbed)
KWRI		2.00	NA

Number of Truckloads Required Rounded Down to Whole Number

		KHOP	
		Pallets (by TL)	RS (by Flatbed)
KWRI		0.78	NA

Number of Pallets Remaining for Transport

[% of TL remaining x 25,000 lbs / Avg Pallet Wt]

		KHOP	
		Pallets (by TL)	RS (by Flatbed)
KWRI		1.00	NA

Number of Pallets for Transport (Rounded Up)

Figure 14: Truckload/LTL Example

Thus, in the C-17 Boomerang example, two Truckloads were utilized along with an LTL shipment of one pallet. This calculates to a cost of $871.37 per Truckload and $506.61 per Less-Than-Truckload shipment. The total cost of this Boomerang shipment is ($871.37 x 2) + $506.61 = $2249.35/sortie.

Calculations for all fifty identified sorties were made to determine the overall Less-Than-Truckload/Flatbed and Truckload/Less-Than-Truckload/Flatbed costs for the quarter. The resulting figures were then multiplied by four to give a yearly estimate as to the costs of shipping the offloaded cargo by these two options as opposed to air transport.

Rail Costs

Rail costs were determined by using historical figures of rail transport costs found published research articles. This rate was given in cents per Ton-Mile for freight transported. The author used two sources to determine the baseline cents per Ton-Mile cost for freight transport. The first was the research article entitled "Cities, Regions and the Decline of Transport Costs" by Edward Glaeser and Janet Kohlhase of the Harvard Institute of Economic Research. Based on their research and National Transportation Board Statistics, these authors determined that the cost of rail transport historically was 2.4 cents per Ton-Mile (Glaeser, 2003:35). An additional source of information about the cost of rail transport was that by J-P Rodrigue, C. Comtois and B. Slack, in their book <u>The Geography of Transport Systems</u>. Based on their chart, "Freight Transport Costs in Cents Per Ton-Mile" (located in Figure 5 above), the cost or rail transport historically is around 2.5 cents per Ton-Mile for freight transported (Rodrigue, 2009).

Based on these two sources, the cost of rail is somewhere around 2.4 and 2.5 cents per Ton-Mile. For the purposes of this paper, the author used the figure of 2.4 cent per Ton-Mile based on the research methods of Glaeser and Kohlhase and the fact that their data also comprises National Transportation Board Statistics regarding the costs of transport.

In order to calculate the rail costs for transport of cargo between the APODs on the West/East Coast and the cargo's inland destinations, the author determined the ground distance between the two locations using Google Maps. The author assumed that rail transport options near the departure and arrival points would be present and available for use in transporting the cargo. The table below details the distances between the APODs and Cargo Destinations:

Table 7: Ground Distances for Rail Transport

Ground Distances	KWRI	KDOV	KCHS	KTCM	KSUU
KPOB	520	440	230		
KHOP	900	835	610		
KGRF				10	725
KGRK	1690	1600	1210	2240	1790
KBIF	2160	2075	1740	1760	1205
KVPS	1220	1140	565		
KNZY				1225	520

The next table details the total amount of cargo to be transported via rail from each APOD to each destination over the 3rd Quarter, 2011 on the fifty selected missions.

Table 8: Cargo to be Transported by Rail (3rd Quarter, 2011)

Cargo to Move	KWRI	KDOV	KCHS	KTCM	KSUU
KPOB	322.51	102.4	109.55		
KHOP	308.62	59	22		
KGRF				106.8	19
KGRK	81.1	185.85	0	0	0
KBIF	0	16.8	0	0	0
KVPS	0	46.3	0		
KNZY				0	81.795

Using a rail transport cost of 2.4 cents per Ton-Mile, the costs of transporting cargo via rail for the 3rd Quarter of 2011 are determined in the table below.

Table 9: Rail Transport Costs for Selected APODs/Destinations

Rail Costs ($0.024/Ton-Mile) [1]

	KWRI	KDOV	KCHS	KTCM	KSUU	Totals
KPOB	$ 4,024.92	$ 1,081.34	$ 604.72			***$ 5,710.98***
KHOP	$ 6,666.19	$ 1,182.36	$ 322.08			***$ 8,170.63***
KGRF	$ -	$ -	$ -	$ 25.63	$ 330.60	***$ 356.23***
KGRK	$ 3,289.42	$ 7,136.64	$ -	$ -	$ -	***$ 10,426.06***
KBIF	$ -	$ 836.64	$ -	$ -	$ -	***$ 836.64***
KVPS	$ -	$ 1,266.77	$ -			***$ 1,266.77***
KNZY				$ -	$ 1,020.80	***$ 1,020.80***
						$ 27,788.11

1: Source: Glaeser, Harvard Institute of Economic Research, 2003

Overall Savings Calculations

In order to determine the overall savings, the author used three main scenarios. The three main scenarios consist of cargo being offloaded at West/East Coast bases (rather than flying the cargo to its destinations) and being 1) Shipped via Less-Than-Truckload and Flatbed to its various destinations, 2) Shipped via Truckload, Less-Than-Truckload and Flatbed to its various destinations, or 3) Shipped via Rail to its various destinations.

To calculate the savings potential of these three options, the author first had to determine the cost savings in flying costs. Once these savings were determined, the cost of each of the transport options was subtracted from the savings figure to determine an overall savings amount for each option.

Summary

The methodology of this case study consisted of analyzing missions from May – Oct 2011 to determine cost-saving opportunities in which multi-modal transport could be utilized. The timeframe of the analysis was further refined to the 3rd Quarter, 2011 (Jul – Sep) in order to have a representative sample of missions (n = 1439) that could be used to estimate yearly savings if the methods proposed in this paper are utilized.

In the 3rd Quarter 2011, fifty of the 1439 missions were identified as cost-savings opportunities and these missions were analyzed in detail for flying, truck and rail costs to determine the cost differences between the methods. The author calculated four types of costs (flying fuel, total fuel, variable, and operational) incurred as a result of flying cargo to inland destinations. The author then recalculated the costs based on the premise of dropping the cargo off at West/East Coast bases for multi-modal transport in order to estimate the potential savings of pursuing that option.

Once that savings figure was determined, the author then had to determine the costs of moving the cargo via multi-modal transport (truck and rail). In order to determine the truck costs, the author determined a typical load of cargo on a sortie that proceeds to various inland destinations and used that configuration to determine the costs of Truckload, Less-than-Truckload, and Flatbed transport of that cargo. Next, the author determined the costs of rail shipment using historical rates in cents per Ton-Mile multiplied by the weight and distance traveled between the West/East Coast bases and various inland destinations.

To determine the actual savings of utilizing multi-modal transport, the author first determined the cost savings in flying costs and then subtracted the costs of the multi-modal transport options to determine overall savings.

IV. Analysis and Results

Chapter Overview

This chapter will detail the analysis and results of the author's case study of the cargo missions flown during the 3rd Quarter, 2011. Following a discussion of the results, the author will readdress the investigative questions posed in the Introduction section to gain a fuller understanding of the case study and its implications.

Analysis and Results

In total, the author identified fifty (50) missions of the 1439 analyzed that had opportunities for C-5 and C-17 aircraft to achieve substantial cost savings based on dropping off cargo at West/East Coast bases for multi-modal transport. Of these fifty missions, 44 were C-17 missions and 6 were C-5 missions. The figure below shows the identified missions:

C-17 Missions:

Boomerangs:	# Flown
CYQX-KHOP-KWRI	1
ETAR-KPOB-KWRI	5
ETAD-KPOB-KWRI	2
CYQX-KPOB-KWRI	1
ETAD-KPOB-KDOV	1
ETAR-KPOB-KDOV	2
ETAD-KHOP-KDOV	1
ETAD-KHOP-KWRI	2
Total	15

Leapfrogs:	
KDOV-KGRK-KCHS	1
KBGR-KGRF-KTCM	1
KWRI-KGRK-KTCM	3
KDOV-KBIF-KTCM	1
CYQX-KGRF-KTCM	2
KDOV-KGRK-KWRI	1
KWRI-KGRK-KCHS	1
KDOV-KGRK-KDOV	2
KHOP-KGRF-KTCM	1
KHOP-KGRF-KSUU	1
Total	14

Maine-iacs:	
ETAR-KBGR-KPOB-KTCM	1
ETAD-KBGR-KHOP-KTCM	1
ETAR-KBGR-KHOP-KCHS	1
ETAD-KBGR-KHOP-KWRI	1
ETAR-KBGR-KHOP-KSUU	1
ETAD-KBGR-KPOB-KTCM	2
ETAR-KBGR-KHOP-KTCM	1
ETAR-KBGR-KPOB-KCHS	1
Total	9

C-5 Missions:

Boomerangs:	# Flown
LERT-KHOP-KDOV	1
Total	1

Leapfrogs:	
KDOV-KNZY-KSUU	1
KBGR-KNZY-KSUU	1
KDOV-KGRK-KDOV	1
Total	3

Maine-iacs:	
LERT-KBGR-KVPS-KDOV	1
ETAD-KBGR-KGRK-KDOV	1
Total	2

Totals: 6

Paratroops:		
ETAD-KPOB-KCHS	2	
CYQX-KPOB-KCHS	1	
ETAR-KHOP-KCHS	1	
ETAR-KPOB-KCHS	2	
Total	6	
Totals:	**44**	

Figure 15: C-17/C-5 Savings Opportunities

Using the methodology described in the previous section, the author calculated the below figures for the savings potential based on the flying costs of the fifty missions:

	# Flown	Flying Fuel Delta	Total Fuel Delta
C-17/C-5 Total:	**50**	**$ 979,754.55**	**$ 1,003,568.79**
		Variable Delta	**Op Delta**
		$ 1,553,029.20	**$ 2,818,667.24**
		Flt Hours Delta	**Mission Hours Delta**
		97.78	**236.28**

Figure 16: C-17/C-5 Flying Savings of Fifty Identified Missions

The numbers below each green category represent the "savings." The actual calculation worksheet for the flying figures is shown in Appendix D.

In order to determine the overall savings potential of these fifty missions, the author then had to determine the costs of the three identified options of ground transport for the 3rd Quarter, 2011. The figure below shows a comparison of the calculations of the three options below:

LTL/Flatbed Total Cost for Quarter	TL/LTL/Flatbed Total Cost for Quarter	Rail Total Cost for Quarter
$ 233,715.53	$135,230.39	$ 27,788.11

Figure 17: Ground Cost Comparison for Fifty Identified Missions

The full calculation worksheet for the ground transport calculations are shown in Appendices E & F.

The calculations for the overall savings potential of the multi-modal transport options is computed by subtracting the ground transport costs from the flying savings calculated above. The figures below show the resulting numbers for the 3rd Quarter, 2011 for the fifty identified missions.

3rd Quarter 2011						
	Flying Fuel Savings	Operational Cost Savings	Variable Cost Savings	Flying Hours Savings	Total Fuel Savings	Mission Hours Savings
C-17/C-5 Total:	$ 979,754.55	$ 2,818,667.24	$ 1,553,029.20	97.78	$ 1,003,568.79	236.28
LTL / Flatbed Costs		$ 233,715.53	$ 233,715.53			
Realized Savings:	*$ 979,754.55*	*$ 2,584,951.71*	*$ 1,319,313.67*	*97.78*	*$ 1,003,568.79*	*236.28*
	Flying Fuel Delta	Operational Cost Savings	Variable Cost Savings	Flying Hours Savings	Total Fuel Delta	Mission Hours Delta
C-17/C-5 Total:	$ 979,754.55	$ 2,818,667.24	$ 1,553,029.20	97.78	$ 1,003,568.79	236.28
TL / LTL/ Flatbed Costs		$ 135,230.39	$ 135,230.39			
Realized Savings:	*$ 979,754.55*	*$ 2,683,436.85*	*$ 1,417,798.81*	*97.78*	*$ 1,003,568.79*	*236.28*
	Flying Fuel Delta	Operational Cost Savings	Variable Cost Savings	Flying Hours Savings	Total Fuel Delta	Mission Hours Delta
C-17/C-5 Total:	$ 979,754.55	$ 2,818,667.24	$ 1,553,029.20	97.78	$ 1,003,568.79	236.28
Rail Costs		$ 27,788.11	$ 27,788.11			
Realized Savings:	*$ 979,754.55*	*$ 2,790,879.13*	*$ 1,525,241.09*	*97.78*	*$ 1,003,568.79*	*236.28*

Figure 18: Savings Potential for Fifty Identified Missions During 3rd Quarter, 2011

Based on the above figures, the author calculated an expected yearly savings assuming that the same types of missions will be flown with the same frequencies to the same bases as in the 3rd Quarter 2011. The author recognizes that this scenario will probably not occur however feels that illustrating the potential yearly savings of employing such a concept will demonstrate the impact. The expected yearly figure is below.

Estimated Yearly Savings based on 3rd Quarter 2011						
	Flying Fuel Savings	Operational Cost Savings	Variable Cost Savings	Flying Hours Savings	Total Fuel Savings	Mission Hours Savings
C-17/C-5 Total:	$ 3,919,018.20	$ 11,274,668.96	$ 6,212,116.80	391.12	$ 4,014,275.17	945.12
LTL / Flatbed Costs		$ 934,862.12	$ 934,862.12			
Realized Savings:	*$ 3,919,018.20*	*$ 10,339,806.84*	*$ 5,277,254.68*	*391.12*	*$ 4,014,275.17*	*945.12*
	Flying Fuel Savings	Operational Cost Savings	Variable Cost Savings	Flying Hours Savings	Total Fuel Savings	Mission Hours Savings
C-17/C-5 Total:	$ 3,919,018.20	$ 11,274,668.96	$ 6,212,116.80	391.12	$ 4,014,275.17	945.12
TL / LTL/ Flatbed Costs		$ 540,921.56	$ 540,921.56			
Realized Savings:	*$ 3,919,018.20*	*$ 10,733,747.40*	*$ 5,671,195.24*	*391.12*	*$ 4,014,275.17*	*945.12*
	Flying Fuel Savings	Operational Cost Savings	Variable Cost Savings	Flying Hours Savings	Total Fuel Savings	Mission Hours Savings
C-17/C-5 Total:	$ 3,919,018.20	$ 11,274,668.96	$ 6,212,116.80	391.12	$ 4,014,275.17	945.12
Rail Costs		$ 111,152.46	$ 111,152.46			
Realized Savings:	*$ 3,919,018.20*	*$ 11,163,516.50*	*$ 6,100,964.34*	*391.12*	*$ 4,014,275.17*	*945.12*

Figure 19: Estimated Yearly Savings Based On 3rd Quarter, 2011 Results

As the results above show, there is significant savings potential in utilizing multi-modal transport options for cargo traveling from West/East Coast bases to inland destinations versus using aircraft to fly cargo to its intended destinations. Based on the fifty missions identified by the author as savings “opportunities,” the author calculated potential savings of $979,754.55 in flying fuel, $1,003,568.79 in total fuel, $1,319,313.67 in variable cost savings, and $2,584,951.71 in operational cost savings during the 3rd Quarter of 2011. Additionally, there are also great savings in flying hours of aircraft and mission hours of aircraft (97.78 and 236.28 respectively) that would free these aircraft up to fly additional

C-17/C-5 missions, reducing strain on the aircraft fleet and reducing the number of crews required to fly scheduled missions. The above figures were calculated assuming a ground transport mode of LTL/Flatbed was utilized. Greater savings would be realized by using TL/LTL/Flatbed or rail transport. Multiplying these findings by four to estimate a yearly amount generates an even more significant amount of savings and beneficial mission impact.

Investigative Questions Answered

The following questions were posed in the Introduction section for questions to be answered within this proposal:

1) What are the characteristics of air, rail, and truck freight transportation?

2) What are the basics of a redeployment or reset of Army equipment?

3) What are the fuel, variable, and operational costs of operating C-17 and C-5 aircraft between the West/East Coast bases and inland CONUS destinations?

4) What is the cost of transporting equipment via truck and/or rail from select West/East Coast bases to inland CONUS destinations?

5) What are the cost savings between transporting cargo from select West/East Coast bases by rail/truck versus air?

6) What are the other benefits from utilizing multi-modal transport from West/East Coast bases (flight hours savings, mission hours, etc)?

7) What is the additional workload for Aerial Ports at these selected West/East Coast bases and can they absorb the additional capacity in this proposal?

8) Are rail options feasible at the selected cargo debarkation locations?

Questions 1-6 were covered in depth during the Background, Methodology, and Analysis sections. Questions 7 and 8, however, require more discussion as they have not been discussed or examined in detail up until this point.

Question 7 asks about the additional workload for Aerial Ports at the selected West/East Coast bases and whether or not they can absorb the additional capacity. Figure 8 above details the additional cargo requirements at each proposed APOD and to which destination the offloaded cargo will proceed from that APOD. In order to gain a greater understanding on whether or not the APODs could support those additional cargo requirements, the author conducted a TELECON with AMC/A4TC to discuss. Based on information provided by AMC/A4TC, the numbers generated by the fifty missions for additional cargo offload requirements were not significant enough to be of concern and the APODs identified could support those additional downloads (Finney, 2012). Some additional considerations for the cargo offload were also provided by AMC/A4TC to ensure that the cargo offload/transfer would not encounter significant issues. These considerations include:

1) Scheduling inbound cargo offloads (when possible) to de-conflict with heavy outbound cargo requirements or surges

2) Coordinating with cargo's owning unit to provide a unit POC at the offload location to assist with cargo transfer to truck/rail and accountability of cargo

3) A manpower increase in ATOC personnel (if necessary) to handle additional workload generated by proposal (Finney, 2012)

Question 8 asks whether or not rail options are feasible at cargo debarkation points (APODs). Further discussions with AMC/A4TC about the possibility of rail transport from selected APODs determined that the feasibility of rail transport from selected APODs is questionable. Although there are railheads located on some APODs (or nearby for those that do not have collocated railheads), the use of these railheads was "non-existent" at or from AMC bases according to AMC/A4TC personnel. On the bases where railheads did exist, the capability of these railheads to support cargo onload/offload operations is unknown but is most likely not able to support cargo requirements as determined in this proposal.

To further illustrate the infeasibility of rail operations from AMC APODs, the author researched a rail feasibility study for Joint Base McGuire-Dix-Lakehurst. The study was conducted by Military Surface Deployment and Distribution Command in March 2011 to determine if a battalion-sized force could be deploy via rail in three or less days. Some of the findings from the study include:

> 1) Rail transport from Joint Base McGuire-Dix-Lakehurst is only accomplished by first transporting equipment from JBMDL by road to Morrisville, PA for onload at the railhead.
>
> 2) The existing off-post rail infrastructure at Morrisville, PA, only supports outloading about 10 railcars per day and is no longer in serviceable condition.
>
> 3) There is no secure location at the Morrisville location, so vehicles and equipment have to be road marched and loaded in the same day. JBMDL does not have sufficient truck loading hardstands in the vicinity of the Morrisville rail spur.
>
> 4) The Morrisville rail spur presents functionality and safety concerns for operations, equipment and personnel during deployment operations. This site's challenges are as follows: (1) The loading ramp is a sub-standard earthen design, which could fail under substantial load; (2) The track structure at Morrisville contains numerous defects that do not meet Army rail standards (UFC 4-860-03, Railroad Track Maintenance & Safety Standards); (3) Force protection is lacking

> at the Morrisville rail spur and compromises the safety and security of military equipment; (4) Current rail deployment procedure inefficiencies often cause unit movement at Fort Dix to miss port of call times wasting time and money (SDDCTEA, March 2011)

Overall, the authors of the study concluded that significant improvements had to be made to the Morrisville railhead in order to conduct operations of any sizable cargo loads from JBMDL. Based on this information and considering that the majority of cargo transits JBMDL (KWRI) for the rail option in this proposal, the author does not deem the rail option to be feasible in its current state.

There were no other rail studies for the other APODs identified in this proposal for the author to conclude as to their feasibility for rail transport. However, based on the above information on JBMDL and that provided by AMC/A4TC, the author feels confident is saying that most AMC APODs will probably not be able to support a rail transport option from at or near their bases without significant infrastructure improvements. For those AMC APODs where a rail transport option is nearby and feasible, additional considerations must be made as to the configuring of cargo for rail transport and the additional manpower and effort in transporting that cargo to the railhead for further transport. In short, the effort, time, and money required to make rail transport a feasible option may override the cost savings potential of employing this option.

Summary

The analysis of the above case study yielded significant results in the way of savings for the US government in employing a multi-modal concept for cargo de-positioning to inland CONUS destinations. The vast majority of savings are generated

due to fuel savings from not having to fly aircraft from West/East Coast Bases to inland destinations and then to their home stations. There are also other variable and operational savings realized by reducing the number of hours flown on AMC aircraft. These hours saved will also result in a significant amount of mission hours being saved as flight and ground times are reduced by the aircraft that no longer having to transport cargo to inland CONUS destinations.

In comparison to flying costs, the costs of truck and rail transport from APODs where cargo was downloaded to the cargos' final destinations are magnitudes less. In fact, the most expensive ground option (Less-Than-Truckload/Flatbed Transport) only amounts to approximately 15% of the variable costs of operating C-17/C-5 aircraft based on the total costs of the cargo moved during the 3rd Quarter, 2011. More savings can be generated by utilizing a mixed Truckload/Less-Than-Truckload/Flatbed option for cargo transport when cargo is able to be loaded and transported as a full Truckload vice LTL cargo. The rail option of transport, when feasible, provides the least expensive method to transport cargo. However, based on deficiencies of AMC's railhead infrastructure at its AMC bases and the challenges associated with moving cargo to nearby accessible railheads (and the deficiencies of those railheads, in turn), the rail option for transport of cargo in such a scenario appears infeasible.

V. Conclusions and Recommendations

Chapter Overview

This chapter touches briefly on the author's conclusions and significance of the research, any recommendations for action and future research, and some rules of thumb for multi-modal transport options.

Conclusions and Significance of Research

The US government has a significant task ahead of it in successfully withdrawing US personnel from Afghanistan in accordance with President Obama's timeline for withdrawal. The first hurdle in this plan will be quickly upon USTRANSCOM and AMC planners as 23,000 troops and some of their equipment will need to be redeployed back to CONUS by September 2012. With this redeployment of personnel from Afghanistan to CONUS bases rapidly approaching, there is potential for great savings by changing the way AMC and USTRANSCOM planners utilize AMC aircraft for these missions and time is of the essence. Rather than having AMC aircraft fly cargo direct to inland destinations, there are ample opportunities for AMC aircraft to offload cargo at their respective home stations on the West/East Coasts and utilize multi-modal transport to move the cargo to its final destinations. Utilizing such an approach saves on fuel costs, variable costs, operational costs, flight hours, and mission hours while having minimal impact on the cargo's home station arrival date.

This research paper analyzed only one quarter (3rd Quarter, 2011) worth of C-17 and C-5 data yet was able to identify at least fifty opportunities for savings by utilizing a multi-modal option of transport. The possible savings for those fifty missions analyzed

resulted in approximately $1M of savings in total fuel, $1.3M-$1.5M of savings in variable costs, $2.5M-$2.8M of savings in operational costs, and significant savings in flying hours (97.78) and mission hours (236.28). Many more opportunities for savings could, and probably do, exist in the missions that AMC flies in support of USTRANSCOM and DoD objectives. Identifying these missions where savings could possibly be attained by effectively utilizing multi-modal transport methods should be a key priority for AMC and USTRANSCOM planners, particularly in the case of the next surge home of US troops prior to the end of September 2012.

Recommendations for Action and Rules of Thumb

Based on the above research, analysis, and conclusions, the author offers up the following recommendations for further action:

1) AMC and USTRANSCOM planners should look at those types of missions identified in this proposal (Boomerangs, Leapfrogs, Maine-iacs, and Paratroops) to identify additional cases where savings can be utilized by using multi-modal transport.

2) Once those missions are identified, coordination should occur between AMC, USTRANSCOM, APODs, and cargo user to coordinate timing of missions, method of transport, and manpower support for additional downloading of cargo from aircraft and uploading of cargo onto ground transport on select missions.

3) AMC, in combination with SDDC, should determine if any AMC APODs can support current or future ground transportation utilizing rail with improvements/ investment in their infrastructure.

In addition to the above recommendations for future action, the author offers up the following rules of thumb based on the results of this analysis:

1) Concentrate on utilizing Trucking as the main transport option for ground transportation until a determination is made regarding Recommendation 3. If Recommendation 3 is infeasible for current and future operations, efforts should be made to institute and refine the ground transport process from APODs to cargo destinations utilizing Trucking options.

2) Coordinate as best as possible for full Truckload transport of cargo from APODs to the cargo's inland destinations in order to save costs. When unable to travel as full TLs, transport cargo via LTL from APOD to cargo destination.

3) In all cases, utilize ground transportation to the maximum extent possible and only use air transportation for truly time sensitive cargo or when ground transport cannot be utilized (i.e. oversized cargo, ammunition, hazardous, etc.).

Summary

There are great potential savings to be realized by utilizing multi-modal transport options on AMC missions where aircraft can proceed to their home station West/Coast bases to offload cargo rather than proceeding to the cargo's inland destinations. Taking advantage of these opportunities will garner considerable savings in fuel costs, variable costs, and operational costs. This money saved is significant based on the current fiscal restraints that the Air Force, Department of Defense, and US government are encountering. Additionally, there are also significant savings in flying hours and mission hours by utilizing this multi-modal approach. The savings in these flight and mission

hours will provide AMC and USTRANSCOM with additional available aircraft and aircrews to operate its ever-expanding requests for air transport from its COCOM customers. Based on these conclusions, the concept of multi-modal transport for depositioning cargo returning to CONUS is definitely an undertaking that the Air Force, AMC, and USTRANSCOM should pursue in the immediate future and as a new standard practice in their operations.

Appendix A- State-by-State Listing of Bases Requiring Rail and Associated Railhead

ACTIVITY	RAILHEAD
ALABAMA	
Anniston AD	Bynum
Fort Rucker	Daleville
ALASKA	
Clear AFS	Clear AFS
Eielson AFB	Eielson AFB
Fort Richardson	Fort Richardson
Fort Wainwright	Fort Wainwright
Port of Anchorage	Anchorage
ARIZONA	
Camp Navajo	Bellemont
Raytheon Missile Systems	Aldona
Yuma Proving Grounds	Blaisdell
ARKANSAS	
Fort Chaffee	Fort Chaffee
Pine Bluff Arsenal	Baldwin
CALIFORNIA	
Beale AFB	Earle
Camp Roberts	McKay
Edwards AFB	Edwards
Fort Irwin (OP)	Yermo
Marine Corp Air Ground Combat Center, 29 Palms (OP)	Nebo, Yermo
Marine Corp Logistics Base, Barstow	Nebo, Yermo
MCB, Camp Pendleton	Oceanside
Military Ocean Terminal Concord (MOTCO)	Port Chicago
NBVC, Port Hueneme	Port Hueneme

ACTIVITY	RAILHEAD
CALIFORNIA (Continued)	
NAWCWD, China Lake (OP)	Spangler
Navy Munitions Command Seal Beach	Westminster
Port of Long Beach	Long Beach
Port of Oakland	Oakland
Port of San Diego	San Diego
Riverbank AAP	Riverbank
Sierra AD	Herlong
Vandenburg AFB	Tangair
COLORADO	
Fort Carson	Kelker
Pinion Canyon	Simpson
Pueblo Chemical Depot	Avondale
CONNECTICUTT	
NSB, New London	New London
DELAWARE	
None	
FLORIDA	
USMC Blount Island Command	Blount Island
Camp Blanding	Starke
Naval Ordinance Test Unit	Jay Jay
Port of Jacksonville	Blount Island
GEORGIA	
Fort Benning	Ochillee, Sand Hill
Fort Stewart	Walthourville
Hunter AAF	Savannah
Marine Corps Logistics Base, Albany	Dosaga
NSB, Kings Bay	Kings Bay

ACTIVITY	RAILHEAD
GEORGIA (continued)	
NSO, (Trident Refit Facility)	Kings Bay
Port of Savannah	Savannah
SWF, Atlantic	Kings Bay
HAWAII	
None	
IDAHO	
Orchard MATES	Orchard
ILLINOIS	
Rock Island Arsenal	Rock Island
INDIANA	
Camp Atterbury	Edinburg
Crane Army Ammunition Activity	Crane
Naval Support Activity, Crane	Crane
IOWA	
Iowa AAP	Middletown
KANSAS	
Fort Riley	Fort Riley
KENTUCKY	
Blue Grass Army Depot	Fort Estill
Fort Campbell	Casky
Fort Knox	Fort Knox
LOUISIANA	
Fort Polk	Daube Jct
MAINE	
Naval Shipyard, Portsmouth	Kittery
MASSACHUSETTS	
Camp Edwards	N. Falmouth

ACTIVITY	RAILHEAD
MARYLAND	
Aberdeen Proving Grounds	Aberdeen
Port of Baltimore	Baltimore
USPFO MD	Havre De Grace
MICHIGAN	
Camp Grayling	Grayling
Detroit Arsenal Tank Plant	Warren
MINNESOTA	
Camp Ripley	Camp Ripley
MISSISSIPPI	
Camp Shelby	Camp Shelby
NCBC, Gulfport	NCBC, Gulfport
MISSOURI	
Fort Leonard Wood	Bundy Jct
USPFO MO	Jefferson City
MONTANA	
Malmstrom AFB	Falls Yard
NEBRASKA	
None	
NEVADA	
Hawthorne AD	Churchill/Thorne
NEW HAMPSHIRE	
Naval Shipyard, Portsmouth	Kittery, Me
NEW JERSEY	
NWS, Earle	Earle
Fort Dix, (OP)	Morrisville, PA
Port of New York/New Jersey	Elizabethport, NJ

ACTIVITY	RAILHEAD
NEW MEXICO	
White Sands Missile Range	Las Cruces
NEW YORK	
Fort Drum	Calcium
Watervliet Arsenal	Watervliet
NORTH CAROLINA	
DESC, Millers Siding (Seymour- Johnson AFB)	Goldsboro
DFSP Selma	Selma
Fort Bragg	Fort Junction
MCAS, Cherry Point	Havelock
MCB Camp Lejeune	Havelock
MOT Sunny Point	Leland
Pope AFB	Fort Junction
Port of Morehead City	Morehead City
Port of Wilmington	Wilmington
NORTH DAKOTA	
None	
OHIO	
Camp Perry	Port Clinton
Lima Army Tank Plant	Lima
Ravenna AAP	Atlas
OKLAHOMA	
Fort Sill	Fort Sill
McAlester AAP	Savanna
OREGON	
None	

ACTIVITY	RAILHEAD
PENNSYLVANIA	
Fort Indiantown Gap (OP)	Harrisburg
Letterkenny AD	Culbertson
Letterkenny Munitions Center	Culbertson
NAVICP, Mechanicsburg	Mechanicsburg
Port of Philadelphia	Philadelphia
Scranton AAP	Scranton
Tobyhanna AD	West Tobyhanna
RHODE ISLAND	
None	
SOUTH CAROLINA	
DFSP, Charleston	Charbulk
Fort Jackson (OP)	Columbia
NWS, Charleston	Inness
Port of Charleston	Charbulk
Shaw AFB	Cane Savannah
SOUTH DAKOTA	
None	
TENNESSEE	
Milan AAP	Milan
Arnold Air Force Station	Tullahoma
Holston AAP	Holston
TEXAS	
Fort Bliss	El Paso
Fort Hood	Killeen
Port of Beaumont	Beaumont
Port of Corpus Christi	Corpus Christi
Red River AD	Defense

ACTIVITY	RAILHEAD
UTAH	
ATK Thiokol (Magna)	Bacchus
ATK Thiokol (Promontory)	Corinne
Deseret Chemical Depot	Clover
Hill AFB	Hill AFB
Tooele AD	Warner
VERMONT	
None	
VIRGINIA	
Fort Eustis	Lee Hall
Fort Lee	Petersburg
Fort Pickett	Blackstone
Marine Corps Base, Quantico	Quantico
Naval Shipyard, Norfolk	Portsmouth
NWS, Yorktown	Lee Hall
Port of Newport News	Newport News
Port of Norfolk (International Terminal)	Norfolk
Radford AAP	Cowan, Pepper
WASHINGTON	
Fort Lewis	Fort Lewis
Indian Island	Bangor
Naval Shipyard, Puget Sound	Bremerton
NSB, Bangor	Bangor
Port of Tacoma	Tacoma
SWF, Pacific	Bangor
Yakima Firing Center	Pomona

Appendix B – Aircraft Costs

New CAIG Cost Element Matrix

(New CAIG Structure) Cost Elements	Cost Included in the Various Cost Categories (TY$ and CY$) Fixed	Var/ Fly Hr	Var/ TAI	Log Cost	Operating Cost	Ownership Costs
N1.0 - Unit Personnel			X	X	X	X
N1.1 - Operations Personnel			X		X	X
N1.1.1 - Pilot			X		X	X
N1.1.2 - Aircrew			X		X	X
N1.1.3 - Crew Technician			X		X	X
N1.1.4 - Command & Control			X		X	X
N1.2 - Maintenance Personnel			X	X	X	X
N1.2.1 - Organizational			X	X	X	X
N1.2.2 - Intermediate			X	X	X	X
N1.2.3 - Ordnance			X	X	X	X
N1.2.4 - Other Maintenance			X	X	X	X
N1.3 - Other Direct Support Personnel			X		X	X
N1.3.1 - Unit Staff			X		X	X
N1.3.2 - Security			X		X	X
N1.3.4 - Other Support			X		X	X
Missing Manpower Costs			X		X	X
N2.0 - Unit Operations		X		X	X	X
N2.1 - Operating Material		X			X	X
N2.1.1 - Energy (Fuel, POL, Electricity)		X			X	X
N2.1.1.1 - AV Fuel		X			X	X
N2.1.1.2 - POL		X			X	X
N2.1.1.3 - Electricity		X			X	X
N2.1.2 - Training Munitions & Expendable Stores		X			X	X
N2.1.2.1 - Ammunition		X			X	X
N2.1.2.2 - Bombs		X			X	X
N2.1.2.3 - Rockets		X			X	X
N2.1.2.4 - Training Missiles		X			X	X
N2.1.2.6 - Pyrotechnics		X			X	X
N2.1.3 - Other Operational Material		X			X	X
N2.2 - Support Services		X		X	X	X

N2.2.1 - Purchased Services		X		X	X	X
N2.2.2 - Transportation		X		X	X	X
N2.2.3 - Other		X		X	X	X
N2.3 - TDY		X		X	X	X
N3.0 - Maintenance		X	X	X	X	X
N3.1 - Organizational Maintenance & Support		X		X	X	X
N3.1.1 - Consumables		X		X	X	X
N3.1.2 - Repair Parts		X		X	X	X
N3.1.3 - DLR		X		X	X	X
N3.1.3.1 - Flying DLR		X		X	X	X
N3.1.3.2 - Non-Flying DLR		X		X	X	X
N3.1.4 - Contract Maintenance Services		X	X	X	X	X
N3.1.4.1 - Interim Contractor Support		X	X	X	X	X
Missing Interim Contractor Support Costs*		X	X		X	X
N3.1.4.2 - Contractor Logistics Support		X	X	X	X	X
N3.1.4.3 - Simulator Operations		X	X	X	X	X
N3.1.4.4 - Other Contractor Support		X	X	X	X	X
N3.3 - Depot Maintenance		X	X	X	X	X
N3.3.1 - Aircraft			X	X	X	X
N3.3.2 - Missile			X	X	X	X
N3.3.3 - Engine		X		X	X	X
N3.3.4 - Other			X	X	X	X
N4.0 - Sustaining Support	X			X	X	X
N4.1 - System Specific Training	X			X	X	X
N4.3 - Operating Equipment Replacement	X			X	X	X
N4.4 - Sustaining Engineering & Prog Mgmt	X			X	X	X
N4.5 - Other Sustaining Support	X			X	X	X
N5.0 - Continuing System Improvements						X
N5.1 - Hardware Modifications						
N5.2 - Software Maintenance & Modifications						X
N6.0 - Indirect Support	X				X	X
N6.1 - Installation Support	X				X	X
N6.1.1 - Base Operating Support	X				X	X

N6.1.2 - Real Property Maintenance	X				X	X
N6.2 - Personnel Support	X				X	X
N6.2.1 - Personnel Administration	X				X	X
N6.2.3 - Medical Support	X				X	X
Modification Costs						X

(Current as of 19 Aug 11) – Source: AFCAP v5.7

Appendix C - Cargo Totals and Breakdown

Cargo Totals

		Weight/STons	Cargo Final Destination							
		TOTAL	KPOB	KHOP	KSVN	KGRF	KGRK	KBIF	KVPS	KNZY
APOD:	KWRI	712.23	322.51	308.62	0		81.1	0	0	
	KDOV	410.35	102.4	59	0		185.85	16.8	46.3	
	KCHS	131.55	109.55	22	0		0	0	0	0
	KTCM	106.8				106.8	0	0		0
	KSUU	100.8				19	0	0		81.795
	Total:	**1461.7**	**534.46**	**389.62**	**0**	**125.8**	**266.95**	**16.8**	**46.3**	**81.795**

Sorties

		Sorties	Cargo Final Destination							
		TOTAL	KPOB	KHOP	KSVN	KGRF	KGRK	KBIF	KVPS	KNZY
APOD:	KWRI	24	12	8	0		4	0	0	
	KDOV	13	3	2	0		6	1	1	
	KCHS	6	5	1	0		0	0	0	0
	KTCM	4				4	0	0		0
	KSUU	3				1	0	0		2
	Total:	**50**	**20**	**11**	**0**	**5**	**10**	**1**	**1**	**2**

Cargo Average/Sortie

			Cargo Final Destination							
			KPOB	KHOP	KSVN	KGRF	KGRK	KBIF	KVPS	KNZY
APOD:	KWRI		26.88	38.58	0.00		20.28	0.00	0.00	
	KDOV		34.13	29.50	0.00		30.98	16.80	46.30	
	KCHS		21.91	22.00	0.00		0.00	0.00	0.00	0.00
	KTCM					26.70	0.00	0.00		0.00
	KSUU					19.00	0.00	0.00		40.90

Historical

	KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY	
	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS
# Pieces (Rnded Up)	7	2	10	1	7	2	2	3	7	3	5	0	11	1
Avg Weight (in lbs)	4686.803	6612.39	5038.9	21691	4500.833	17352.4	4242.444	13627.13	3567.7	39530	5493	0	1597	5432.9
Avg Weight (in STons)	2.343402	3.306195	2.5195	10.8455	2.250417	8.6762	2.121222	6.813567	1.7838	19.765	2.7465	0	0.7985	2.7165
Total Cargo	46032		72080		66211		49366		143564		27465		23000	
Percentages (Plt vs. Cargo)	71%	29%	70%	30%	48%	52%	17%	83%	17%	83%	100%	0%	76%	24%

Cargo Breakdown Totals

		KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY	
-		Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS
KWRI		19.15	7.72	26.97	11.61			3.48	16.79	0.00	0.00	0.00	0.00		
KDOV		24.33	9.81	20.62	8.88			5.32	25.65	2.92	13.88	46.30	0.00		
KCHS		15.62	9.81	15.38	6.62			0.00	0.00	0.00	0.00	0.00	0.00		
KTCM						12.70	14.00	0.00	0.00	0.00	0.00			0.00	0.00
KSUU						9.04	9.96	0.00	0.00	0.00	0.00			31.24	9.66

Cargo Breakdown Totals (Lbs)/Sortie

	-	KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY	
-		Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS
KWRI		38309.20	15442.47	53936.78	23218.22			6969.58	33580.42	0.00	0.00	0.00	0.00		
KDOV		48654.14	19612.53	41245.16	17754.84			10647.73	51302.27	5844.90	27755.10	92600.00	0.00		
KCHS		31230.83	19612.53	30759.10	13240.90			0.00	0.00	0.00	0.00	0.00	0.00		
KTCM						25409.99	27990.01	0.00	0.00	0.00	0.00			0.00	0.00
KSUU						18082.02	19917.98	0.00	0.00	0.00	0.00			62474.17	19320.83

Cargo Breakdown (# of Pallets/RS)/ Sortie

	-	KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY	
-		Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS
KWRI		8.17	2.34	10.70	1.07			1.64	2.46	0.00	0.00	0.00	0.00		
KDOV		10.38	2.97	8.19	0.82			2.51	3.76	1.64	0.70	16.86	0.00		
KCHS		6.66	2.97	6.10	0.61			0.00	0.00	0.00	0.00	0.00	0.00		
KTCM						5.65	1.61	0.00	0.00	0.00	0.00			0.00	0.00
KSUU						4.02	1.15	0.00	0.00	0.00	0.00			39.12	3.56

Rounded Cargo Breakdown (# of Pallets/RS) /Sortie

	-	KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY	
-		Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS
KWRI		9.00	3.00	11.00	2.00			2.00	3.00	0.00	0.00	0.00	0.00		
KDOV		11.00	3.00	9.00	1.00			3.00	4.00	2.00	1.00	17.00	0.00		
KCHS		7.00	3.00	7.00	1.00			0.00	0.00	0.00	0.00	0.00	0.00		
KTCM						6.00	2.00	0.00	0.00	0.00	0.00			0.00	0.00
KSUU						5.00	2.00	0.00	0.00	0.00	0.00			40.00	4.00

Rolling Stock Total Pounds/ Sortie

	-	KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY	
-		Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS
KWRI		N/A	15442.47	N/A	23218.22			N/A	33580.42	N/A	0.00	N/A	0.00		
KDOV		N/A	19612.53	N/A	17754.84			N/A	51302.27	N/A	27755.10	N/A	0.00		
KCHS		N/A	19612.53	N/A	13240.90			N/A	0.00	N/A	0.00	N/A	0.00		
KTCM						N/A	27990.01	N/A	0.00	N/A	0.00			N/A	0.00
KSUU						N/A	34704.80	N/A	0.00	N/A	0.00			N/A	19320.83

Rolling Stock Flatbeds Required (1 req/25K)/ Sortie

	-	KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY	
-		Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS
KWRI		N/A	0.62	N/A	0.93			N/A	1.34	N/A	0.00	N/A	0.00		
KDOV		N/A	0.78	N/A	0.71			N/A	2.05	N/A	1.11	N/A	0.00		
KCHS		N/A	0.78	N/A	0.53			N/A	0.00	N/A	0.00	N/A	0.00		
KTCM						N/A	1.12	N/A	0.00	N/A	0.00			N/A	0.00
KSUU						N/A	1.39	N/A	0.00	N/A	0.00			N/A	0.77

Rolling Stock Flatbeds Required (1 req/25K)/ Sortie

	-	KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY	
-		Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS	Pallets	RS
KWRI		N/A	1.00	N/A	1.00			N/A	2.00	N/A	0.00	N/A	0.00		
KDOV		N/A	1.00	N/A	1.00			N/A	3.00	N/A	2.00	N/A	0.00		
KCHS		N/A	1.00	N/A	1.00			N/A	0.00	N/A	0.00	N/A	0.00		
KTCM						N/A	2.00	N/A	0.00	N/A	0.00			N/A	0.00
KSUU						N/A	2.00	N/A	0.00	N/A	0.00			N/A	1.00

Appendix D – Flying Figure Calculations

3rd Quarter, 2011 (1 Jul - 30 Sep)		C-17 Missions					
		Flying Fuel Delta	Op Delta	Variable Delta	Flt Hours Delta	Total Fuel Delta	Mission Hours Delta
Boomerangs:	# Flown						
CYQX-KHOP-KWRI	1	$ 29,345.10	$ 64,548.20	$ 39,413.40	3.10	$ 29,768.62	5.85
ETAR-KPOB-KWRI	5	$ 86,142.06	$ 189,480.20	$ 115,697.40	9.10	$ 88,259.67	22.85
ETAD-KPOB-KWRI	2	$ 37,107.35	$ 81,622.24	$ 49,838.88	3.92	$ 37,954.39	9.42
CYQX-KPOB-KWRI	1	$ 16,187.13	$ 35,605.62	$ 21,740.94	1.71	$ 16,610.66	4.46
ETAD-KPOB-KDOV	1	$ 16,660.44	$ 36,646.72	$ 22,376.64	1.76	$ 17,083.96	4.51
ETAR-KPOB-KDOV	2	$ 28,777.13	$ 63,298.88	$ 38,650.56	3.04	$ 29,624.17	8.54
ETAD-KHOP-KDOV	1	$ 24,896.00	$ 54,761.86	$ 33,437.82	2.63	$ 25,319.52	5.38
ETAD-KHOP-KWRI	2	$ 53,957.11	$ 118,685.40	$ 72,469.80	5.70	$ 54,804.16	11.20
Total	15	**$ 293,072.31**	**$ 644,649.12**	**$ 393,625.44**	**30.96**	**$ 299,425.14**	**72.21**
Leapfrogs:							
KDOV-KGRK-KCHS	1	$ 41,556.44	$ 91,408.58	$ 55,814.46	4.39	$ 41,979.96	7.14
KBGR-KGRF-KTCM	1	$ 2,555.86	$ 5,621.94	$ 3,432.78	0.27	$ 2,979.39	3.02
KWRI-KGRK-KTCM	3	$ 44,585.61	$ 98,071.62	$ 59,882.94	4.71	$ 45,856.18	12.96
KDOV-KBIF-KTCM	1	$ 16,755.10	$ 36,854.94	$ 22,503.78	1.77	$ 17,178.63	4.52
CYQX-KGRF-KTCM	2	$ 11,359.39	$ 24,986.40	$ 15,256.80	1.20	$ 12,206.44	6.70
KDOV-KGRK-KWRI	1	$ 55,471.70	$ 122,016.92	$ 74,504.04	5.86	$ 55,895.22	8.61
KWRI-KGRK-KCHS	1	$ 36,728.70	$ 80,789.36	$ 49,330.32	3.88	$ 37,152.22	6.63
KDOV-KGRK-KDOV	2	$ 117,380.38	$ 258,192.80	$ 157,653.60	12.40	$ 118,227.43	17.90
KHOP-KGRF-KTCM	1	$ (662.63)	$ (1,457.54)	$ (889.98)	-0.07	$ (239.11)	2.68
KHOP-KGRF-KSUU	1	$ 11,170.07	$ 24,569.96	$ 15,002.52	1.18	$ 11,593.59	3.93
Total	14	**$ 336,900.63**	**$ 741,054.98**	**$ 452,491.26**	**35.59**	**$ 342,829.94**	**74.09**

Maine-Iacs:		Flying Fuel Delta	Op Delta	Variable Delta	Flt Hours Delta	Total Fuel Delta	Mission Hours Delta
ETAR-KBGR-KPOB-KTCM	1	$ 8,803.53	$ 19,364.46	$ 11,824.02	0.93	$ 9,015.29	3.18
ETAD-KBGR-KHOP-KTCM	1	$ 4,638.42	$ 10,202.78	$ 6,229.86	0.49	$ 4,850.18	2.74
ETAR-KBGR-KHOP-KCHS	1	$ 6,720.97	$ 14,783.62	$ 9,026.94	0.71	$ 6,932.73	2.96
ETAD-KBGR-KHOP-KWRI	1	$ 32,374.27	$ 71,211.24	$ 43,481.88	3.42	$ 33,009.55	5.67
ETAR-KBGR-KHOP-KSUU	1	$ 3,597.14	$ 7,912.36	$ 4,831.32	0.38	$ 3,808.90	2.63
ETAD-KBGR-KPOB-KTCM	2	$ 17,985.70	$ 39,561.80	$ 24,156.60	1.90	$ 18,409.23	6.40
ETAR-KBGR-KHOP-KTCM	1	$ 4,638.42	$ 10,202.78	$ 6,229.86	0.49	$ 4,850.18	2.74
ETAR-KBGR-KPOB-KCHS	1	$ (3,313.16)	$ (7,287.70)	$ (4,449.90)	-0.35	$ (3,101.40)	1.90
Total	9	**$ 75,445.30**	**$ 165,951.34**	**$ 101,330.58**	**7.97**	**$ 77,774.67**	**28.22**
Paratroops:							
ETAD-KPOB-KCHS	2	$ 4,354.43	$ 9,578.12	$ 5,848.44	0.46	$ 5,201.48	5.96
CYQX-KPOB-KCHS	1	$ 2,650.52	$ 5,830.16	$ 3,559.92	0.28	$ 3,074.05	3.03
ETAR-KHOP-KCHS	1	$ 11,264.73	$ 24,778.18	$ 15,129.66	1.19	$ 11,688.25	3.94
ETAR-KPOB-KCHS	2	$ 2,271.88	$ 4,997.28	$ 3,051.36	0.24	$ 3,118.92	5.74
Total	6	**$ 20,541.57**	**$ 45,183.74**	**$ 27,589.38**	**2.17**	**$ 23,082.70**	**18.67**
		Flying Fuel Delta	Op Delta	Variable Delta	Flt Hours Delta	Total Fuel Delta	Mission Hours Delta
C-17 Totals:	**44**	**$ 725,959.81**	**$ 1,596,839.18**	**$ 975,036.66**	**76.69**	**$ 743,112.45**	**193.19**

3rd Quarter, 2011 (1 Jul - 30 Sep)		C-5 Missions					
		Flying Fuel Delta	Op Delta	Variable Delta	Flt Hours Delta	Total Fuel Delta	Mission Hours Delta
Boomerangs:	# Flown						
LERT-KHOP-KDOV	1	$ 27,196.59	$ 130,930.84	$ 61,937.56	2.26	$ 28,104.99	5.01
Total	1	$ 27,196.59	$ 130,930.84	$ 61,937.56	2.26	$ 28,104.99	5.01
Leapfrogs:							
KDOV-KNZY-KSUU	1	$ 8,423.72	$ 40,553.80	$ 19,184.20	0.70	$ 9,332.12	3.45
KBGR-KNZY-KSUU	1	$ 14,801.68	$ 71,258.82	$ 33,709.38	1.23	$ 15,710.08	3.98
KDOV-KGRK-KDOV	1	$ 74,008.42	$ 356,294.10	$ 168,546.90	6.15	$ 74,916.82	8.90
Total	3	$ 97,233.83	$ 468,106.72	$ 221,440.48	8.08	$ 99,959.03	16.33
Maine-iacs:							
LERT-KBGR-KVPS-KDOV	1	$ 42,840.65	$ 206,245.04	$ 97,565.36	3.56	$ 44,354.65	9.06
ETAD-KBGR-KGRK-KDOV	1	$ 86,523.67	$ 416,545.46	$ 197,049.14	7.19	$ 88,037.67	12.69
Total	2	$ 129,364.32	$ 622,790.50	$ 294,614.50	10.75	$ 132,392.32	21.75
		Flying Fuel Delta	Op Delta	Variable Delta	Flt Hours Delta	Total Fuel Delta	Mission Hours Delta
C-5 Totals:	6	$ 253,794.74	$ 1,221,828.06	$ 577,992.54	21.09	$ 260,456.34	43.09
[redacted]							
	# Flown	Flying Fuel Delta	Op Delta	Variable Delta	Flt Hours Delta	Total Fuel Delta	Mission Hours Delta
C-17/C-5 Total:	50	$ 979,754.55	$ 2,818,667.24	$ 1,553,029.20	97.78	$ 1,003,568.79	236.28

Appendix E – Trucking Costs

Pallets/RS per Sortie

	KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY	
	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)
KWRI	9.00	1.00	11.00	1.00			2.00	2.00	0.00	0.00	0.00	0.00		
KDOV	11.00	1.00	9.00	1.00			3.00	3.00	2.00	0.00	17.00	0.00		
KCHS	7.00	1.00	7.00	1.00			0.00	0.00	0.00	0.00	0.00	0.00		
KTCM					6.00	2.00	0.00	0.00	0.00	0.00			0.00	0.00
KSUU					5.00	2.00	0.00	0.00	0.00	0.00			36.00	1.00

Rates for Transport

-	KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY	
	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)
KWRI	$ 286.07	$ 669.84	$ 506.61	$ 1,013.22			$ 771.28	$ 1,872.00	$ 724.29	$ 2,427.75	$ 635.90	$ 1,271.79		
KDOV	$ 246.87	$ 614.25	$ 469.76	$ 939.51			$ 749.93	$ 1,798.29	$ 724.29	$ 2,384.46	$ 599.04	$ 1,198.08		
KCHS	$ 234.00	$ 519.48	$ 346.32	$ 786.35			$ 679.77	$ 1,356.03	$ 657.49	$ 1,967.94	$ 288.41	$ 675.31		
KTCM					$ 238.10	$ 456.30	$ 861.11	$ 2,340.00	$ 666.26	$ 1,999.53			$ 333.89	$ 1,416.87
KSUU					$ 416.52	$ 780.98	$ 792.11	$ 1,917.34	$ 574.42	$ 1,280.05			$ 223.84	$ 733.94

LTL/Flatbed Transport Cost per Sortie

-	KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY	
	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)
KWRI	$ 2,574.63	$ 669.84	$ 5,572.71	$ 1,013.22			$ 1,542.56	$ 3,744.00	$ -	$ -	$ -	$ -		
KDOV	$ 2,715.57	$ 614.25	$ 4,227.84	$ 939.51			$ 2,249.79	$ 5,394.87	$ 1,448.58	$ -	$ 10,183.68	$ -		
KCHS	$ 1,638.00	$ 519.48	$ 2,424.24	$ 786.35			$ -	$ -	$ -	$ -	$ -	$ -		
KTCM					$ 1,428.60	$ 912.60	$ -	$ -	$ -	$ -			$ -	$ -
KSUU					$ 2,082.60	$ 1,561.96	$ -	$ -	$ -	$ -			$ 8,058.24	$ 733.94

LTL/Flatbed Transport Cost for Entire Quarter

-	KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY	
	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)	Pallets (by LTL)	RS (by Flatbed)
KWRI	$ 30,895.56	$ 8,038.08	$ 44,581.68	$ 8,105.76			$ 6,170.24	$ 14,976.00	$ -	$ -	$ -	$ -		
KDOV	$ 8,146.71	$ 1,842.75	$ 8,455.68	$ 1,879.02			$ 13,498.74	$ 32,369.22	$ 1,448.58	$ -	$ 10,183.68	$ -		
KCHS	$ 8,190.00	$ 2,597.40	$ 2,424.24	$ 786.35			$ -	$ -	$ -	$ -	$ -	$ -		
KTCM					$ 5,714.40	$ 3,650.40	$ -	$ -	$ -	$ -			$ -	$ -
KSUU					$ 2,082.60	$ 1,561.96	$ -	$ -	$ -	$ -			$ 16,116.48	$ -
Totals:	$ 47,232.27	$ 12,478.23	$ 55,461.60	$ 10,771.13	$ 7,797.00	$ 5,212.36	$ 19,668.98	$ 47,345.22	$ 1,448.58	$ -	$ 10,183.68	$ -	$ 16,116.48	$ -

$ 233,715.53

Rate for Transport (TL)

	KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY	
-	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)
KWRI	$ 509.20	$ 669.84	$ 871.37	$ 1,013.22			$ 1,609.92	$ 1,872.00	$ 2,087.87	$ 2,427.75	$ 1,271.79	$ 1,271.79		
KDOV	$ 488.80	$ 614.25	$ 807.98	$ 939.51			$ 1,546.53	$ 1,798.29	$ 2,050.64	$ 2,384.46	$ 1,198.08	$ 1,198.08		
KCHS	$ 425.14	$ 519.48	$ 595.67	$ 786.35			$ 1,166.19	$ 1,356.03	$ 1,692.43	$ 1,967.94	$ 675.31	$ 675.31		
KTCM					$ 403.65	$ 456.30	$ 2,054.05	$ 2,340.00	$ 1,679.61	$ 1,999.53			$ 1,416.87	$ 1,416.87
KSUU					$ 716.41	$ 780.98	$ 1,745.31	$ 1,917.34	$ 1,165.20	$ 1,280.05			$ 733.94	$ 733.94

Total Weight/TL Capacity (25000 lbs)

	KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY	
-	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)
KWRI	1.53	NA	2.16	NA			0.28	NA	0.00	NA	0.00	NA		
KDOV	1.95	NA	1.65	NA			0.43	NA	0.23	NA	3.70	NA		
KCHS	1.25	NA	1.23	NA			0.00	NA	0.00	NA	0.00	NA		
KTCM					1.02	NA	0.00	NA	0.00	NA			0.00	NA
KSUU					0.72	NA	0.00	NA	0.00	NA			2.50	NA

Number of TLs

	KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY	
-	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)
KWRI	1.00	NA	2.00	NA			0.00	NA	0.00	NA	0.00	NA		
KDOV	2.00	NA	1.00	NA			0.00	NA	0.00	NA	3.00	NA		
KCHS	1.00	NA	1.00	NA			0.00	NA	0.00	NA	0.00	NA		
KTCM					1.00	NA	0.00	NA	0.00	NA			0.00	NA
KSUU					0.00	NA	0.00	NA	0.00	NA			2.00	NA

Pallets Remaining for LTL Transport

	KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY	
-	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)
KWRI	2.84	NA	0.78	NA			1.64	NA	0.00	NA	0.00	NA		
KDOV	0.00	NA	3.22	NA			2.51	NA	1.64	NA	3.20	NA		
KCHS	1.33	NA	1.14	NA			0.00	NA	0.00	NA	0.00	NA		
KTCM					0.09	NA	0.00	NA	0.00	NA			0.00	NA
KSUU					4.02	NA	0.00	NA	0.00	NA			7.81	NA

Pallets Remaining for LTL Transport (Rounded Up)

	KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY	
-	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (byTL)	RS (by Flatbed)	Pallets (byTL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)
KWRI	3.00	NA	1.00	NA			2.00	NA	0.00	NA	0.00	NA		
KDOV	0.00	NA	4.00	NA			3.00	NA	2.00	NA	4.00	NA		
KCHS	2.00	NA	2.00	NA			0.00	NA	0.00	NA	0.00	NA		
KTCM					1.00	NA	0.00	NA	0.00	NA			0.00	NA
KSUU					5.00	NA	0.00	NA	0.00	NA			8.00	NA

TL/Flatbed Cost/Sortie

	KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY	
-	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (byTL)	RS (by Flatbed)	Pallets (byTL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)
KWRI	$ 509.20	$ 669.84	$ 1,742.74	$ 1,013.22			$ -	$ 3,744.00	$ -	$ -	$ -	$ -		
KDOV	$ 977.60	$ 614.25	$ 807.98	$ 939.51			$ -	$ 5,394.87	$ -	$ -	$ 3,594.24	$ -		
KCHS	$ 425.14	$ 519.48	$ 595.67	$ 786.35			$ -	$ -	$ -	$ -	$ -	$ -		
KTCM					$ 403.65	$ 912.60	$ -	$ -	$ -	$ -			$ -	$ -
KSUU					$ -	$ 1,561.96	$ -	$ -	$ -	$ -			$ 1,467.88	$ 733.94

LTL Cost/Sortie

	KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY	
-	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (byTL)	RS (by Flatbed)	Pallets (byTL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)	Pallets (by TL)	RS (by Flatbed)
KWRI	$ 858.21	NA	$ 506.61	NA			$ 1,542.56	NA	$ -	NA	$ -	NA		
KDOV	$ -	NA	$ 1,879.04	NA			$ 2,249.79	NA	$ 1,448.58	NA	$ 2,396.16	NA		
KCHS	$ 468.00	NA	$ 692.64	NA			$ -	NA	$ -	NA	$ -	NA		
KTCM					$ 238.10	NA	$ -	NA	$ -	NA			$ -	NA
KSUU					$ 2,082.60	NA	$ -	NA	$ -	NA			$ 1,790.72	NA

	KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY		TL/LTL/ Flatbed Cost/Sortie
-	Pallets (by TL & LTL)	RS (by Flatbed)	Pallets (by TL & LTL)	RS (by Flatbed)	Pallets (by TL & LTL)	RS (by Flatbed)	Pallets (by TL & LTL)	RS (by Flatbed)	Pallets (by TL & LTL)	RS (by Flatbed)	Pallets (by TL & LTL)	RS (by Flatbed)	Pallets (by TL & LTL)	RS (by Flatbed)	
KWRI	$ 1,367.41	$ 669.84	$ 2,249.35	$ 1,013.22			$ 1,542.56	$ 1,872.00	$ -	$ 2,427.75	$ -	$ 1,271.79			
KDOV	$ 977.60	$ 614.25	$ 2,687.02	$ 939.51			$ 2,249.79	$ 1,798.29	$ 1,448.58	$ 2,384.46	$ 5,990.40	$ 1,198.08			
KCHS	$ 893.14	$ 519.48	$ 595.67	$ 786.35			$ -	$ 1,356.03	$ -	$ 1,967.94	$ -	$ 675.31			
KTCM					$ 641.75	$ 456.30	$ -	$ 2,340.00	$ -	$ 1,999.53			$ -	$ 1,416.87	
KSUU					$ 2,082.60	$ 780.98	$ -	$ 1,917.34	$ -	$ 1,280.05			$ 3,258.60	$ 733.94	

	KPOB		KHOP		KGRF		KGRK		KBIF		KVPS		KNZY		TL/LTL/ Flatbed Total Cost for Quarter
-	Pallets (by TL & LTL)	RS (by Flatbed)	Pallets (by TL & LTL)	RS (by Flatbed)	Pallets (by TL & LTL)	RS (by Flatbed)	Pallets (by TL & LTL)	RS (by Flatbed)	Pallets (by TL & LTL)	RS (by Flatbed)	Pallets (by TL & LTL)	RS (by Flatbed)	Pallets (by TL & LTL)	RS (by Flatbed)	
KWRI	$ 16,408.92	$ 8,038.08	$ 17,994.80	$ 8,105.76			$ 6,170.24	$ 7,488.00	$ -	$ -	$ -	$ -			
KDOV	$ 2,932.80	$ 1,842.75	$ 5,374.04	$ 1,879.02			$ 13,498.74	$ 10,789.74	$ 1,448.58	$ 2,384.46	$ 5,990.40	$ 1,198.08			
KCHS	$ 4,465.70	$ 2,597.40	$ 595.67	$ 786.35			$ -	$ -	$ -	$ -	$ -	$ -			
KTCM					$ 2,567.00	$ 1,825.20	$ -	$ -	$ -	$ -			$ -	$ -	
KSUU					$ 2,082.60	$ 780.98	$ -	$ -	$ -	$ -			$ 6,517.20	$ 1,467.88	
Totals:	**$ 23,807.42**	**$ 12,478.23**	**$ 23,964.51**	**$ 10,771.13**	**$ 4,649.60**	**$ 2,606.18**	**$ 19,668.98**	**$ 18,277.74**	**$ 1,448.58**	**$ 2,384.46**	**$ 5,990.40**	**$ 1,198.08**	**$ 6,517.20**	**$ 1,467.88**	**$ 135,230.39**

Appendix F – Rail Transport Costs

Ground Distances

	KWRI	KDOV	KCHS	KTCM	KSUU
KPOB	520	440	230		
KHOP	900	835	610		
KGRF				10	725
KGRK	1690	1600	1210	2240	1790
KBIF	2160	2075	1740	1760	1205
KVPS	1220	1140	565		
KNZY				1225	520

Rail Costs ($0.024/Ton-Mile) [1]

	KWRI	KDOV	KCHS	KTCM	KSUU	Totals
KPOB	$4,024.92	$1,081.34	$ 604.72			***$ 5,710.98***
KHOP	$6,666.19	$1,182.36	$ 322.08			***$ 8,170.63***
KGRF	$ -	$ -	$ -	$ 25.63	$ 330.60	***$ 356.23***
KGRK	$3,289.42	$7,136.64	$ -	$ -	$ -	***$ 10,426.06***
KBIF	$ -	$ 836.64	$ -	$ -	$ -	***$ 836.64***
KVPS	$ -	$1,266.77	$ -			***$ 1,266.77***
KNZY				$ -	$1,020.80	***$ 1,020.80***
						$ 27,788.11

1: Source: Glaeser, Harvard Institute of Economic Research, 2003

Cargo to Move

	KWRI	KDOV	KCHS	KTCM	KSUU
KPOB	322.51	102.4	109.55		
KHOP	308.62	59	22		
KGRF				106.8	19
KGRK	81.1	185.85	0	0	0
KBIF	0	16.8	0	0	0
KVPS	0	46.3	0		
KNZY				0	81.795

Cost: 0.024

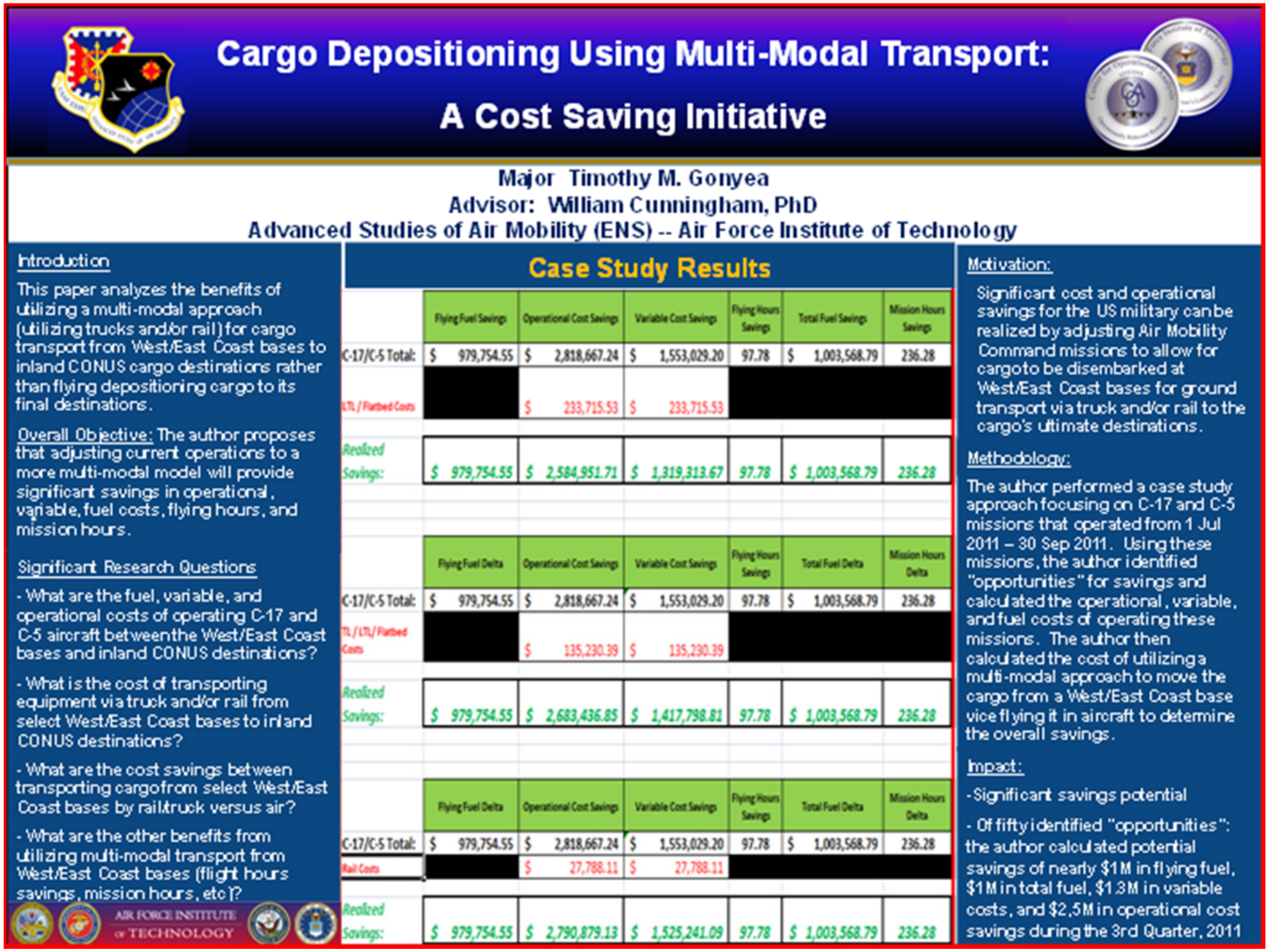
Appendix G - Glossary of Acronyms

18 AF	18th Air Force
AFCAP	Air Force Cost and Performance
AMC	Air Mobility Command
AMC FM/FMAO	Air Mobility Command Financial Management and Comptroller Office
AMC/A4TC	Air Mobility Command Air Transportation and Cargo Office
AMC/A9	Air Mobility Command, Directorate of Analyses, Assessments, and Lessons Learned
AMOCC	Air Mobility Operations Control Center
APOD	Aerial Port of Debarkation
APU	Auxillary Power Unit
ARFORGEN	Army Force Generation
CCDR	Combatabt Commander
COCOM	Combatant Command
CONUS	Continental United States
CPFH	Cost Per Flying Hour
CYQX	Gander International Airport, Canada
DoD	Department of Defense
ETAD	Spangdahlem Air Base, Germany
ETAR	Ramstein Air Base, Germany
FAK	Freight of All Kind
GATES	Global Air Transportation Execution System
ITO	Installation Transportation Officer
JBMDL	Joint Base McGuire-Dix-Lakehurst, New Jersey

JCS	Joint Chiefs of Staff
JOPES	Joint Operation Planning and Execution System
KBGR	Bangor Air Force Base, Maine
KBIF	Biggs Army Airfield, Texas
KCEF	Westover Air Reserve Base, Massachusetts
KCHS	Joint Base Charleston, South Carolina
KDOV	Dover Air Force Base, Delaware
KFFO	Wright Patterson Air Force Base, Ohio
KGRF	Gray Army Airfield, Washington
KGRK	Robert Gray Airfield, Texas
KHOP	Campbell Army Airfield, Kentucky
KJAN	Jackson Air National Guard Base, Mississippi
KMEM	Memphis Air National Guard Base, Tennessee
KMRB	Martinsburg Field, West Virginia
KNZY	Naval Air Station North Island, California
KPOB	Pope Army Airfield, North Carolina
KRIV	March Air Reserve Base, California
KSUU	Travis Air Force Base, California
KSVN	Hunter Army Airfield, Georgia
KSWF	Stewart Air National Guard Base, New York
KTCM	Joint Base Lewis-McChord, Washington

KVPS	Eglin Air Force Base, Florida
KWRI	Joint Base McGuire-Dix-Lakehurst, New Jersey
LERT	Rota Air Base, Spain
LTL	Less-Than-Truckload
MCC	Movement Control Center
O&M	Operations and Maintenance Costs
OPLAN	Operation Plan
OPORD	Operation Order
PAED	Joint Base Elmendorf-Richardson, Alaska
PHIK	Joint Base Pearl Harbor-Hickam, Hawaii
POD	Port of Debarkation
RND	Railroads for National Defense
SAAM	Special Assignment Airlift Mission
SDDC	Military Surface Distribution and Deployment Command
SECAF	Secretary of the Air Force
SecDef	Secretary of Defense
SMS TRANSCOM	Single Mobility System US Transportation Command (website)
SPOD	Sea Port of Debarkation
STRACNET	Strategic Rail Corridor Network
STRAHNET	Strategic Highway Network
TACC	Tanker Airlift Control Center
TELECON	Telephone Conference
TL	Truckload
TPFDD	Time-Phased Force and Deployment Data
TY	Then Year
USAF	United States Air Force
USTRANSCOM	United States Transportation Command
VCPFH	Variable Cost Per Flying Hour

Appendix H – Quad Chart



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14. ABSTRACT
This paper analyzes the benefits of utilizing a multi-modal approach (utilizing trucks and/or rail) for cargo transport from West/East Coast bases to inland CONUS cargo destinations rather than flying cargo to its final destinations. The author proposes that adjusting current operations to a more multi-modal model will provide significant savings in operational, variable, fuel costs, flying hours, and mission hours.

The author performed a case study approach focusing on C-17 and C-5 missions that operated from 1 Jul 2011 – 30 Sep 2011 in determining the cost-savings opportunities utilizing a multi-modal approach. Using these missions, the author identified "opportunities" for savings and calculated the operational, variable, and fuel costs of operating these missions. The author then calculated the cost of utilizing a multi-modal approach to move the cargo from a West/East Coast base vice flying it in aircraft to determine the overall savings.

Based on the paper's findings, significant cost and operational savings for the US military can be realized by adjusting Air Mobility Command missions to allow for cargo to be disembarked at West/East Coast bases for ground transport via truck and/or rail to the cargo's ultimate destinations.

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